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(54) DATA GENERATING PROGRAM AND THREE-DIMENSIONAL FABRICATION SYSTEM

(57) A data generation program and a modeling system capable of generating three-dimensional modeling data for modeling a three-dimensional product and a support column connecting to the three-dimensional product by using a three-dimensional modeling apparatus, considering that the support column is removed from the three-dimensional product, are provided. The data generation program includes instructions for causing a controller of a computer to perform: acquiring three-dimensional data; acquiring an arrangement condition of a support column connecting to the three-dimensional product (S 1); setting an extending direction, a width direction, and a height direction of the support column; adding a cutting margin to a cutting surface (S16); setting the support column of which one end in the extending direction is connected to the added cutting margin (S 19); setting a beam spaced from the three-dimensional product in the extending direction, extending in the width direction, and connected to an other end of the support column in the extending direction (S20); generating three-dimensional modeling data for modeling a modeled object by using a three-dimensional modeling apparatus (S21); and outputting the three-dimensional modeling data (S25).

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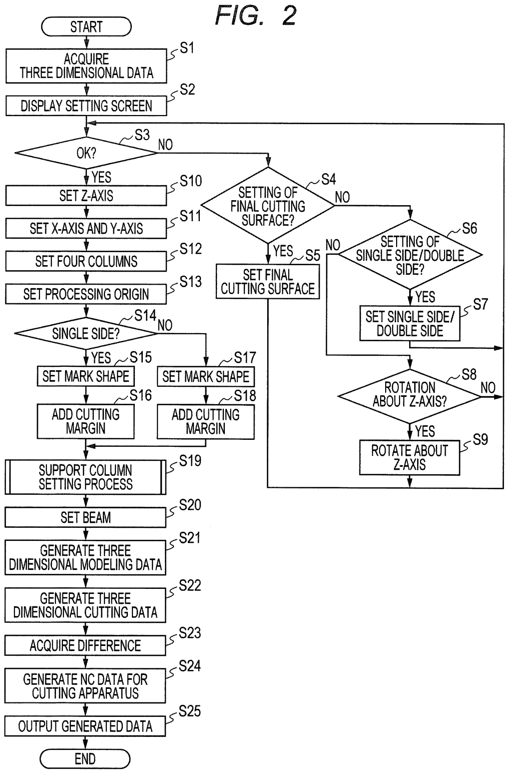
FIG. 2



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Description

TECHNICAL FIELD

[0001] The present invention relates to a data generation program and a three-dimensional modeling system.

BACKGROUND ART

[0002] Conventionally, a three-dimensional product manufacturing system including a three-dimensional modeling apparatus which performs three-dimensional modeling based on three-dimensional modeling data, and a machining apparatus which cuts a three-dimensional shaped object in accordance with NC data to produce a three-dimensional product is known (for example, refer to Patent Literature 1). The NC data is generated based on three-dimensional modeling data.

CITATION LIST

PATENT LITERATURE

[0003] Patent Literature 1: Japanese Patent Application Publication No. 2003-136605

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] The three-dimensional modeling data generated by the above modeling apparatus includes data for modeling a support column. The support column extends in connection with the three-dimensional product and regulates the position of the three-dimensional product during three-dimensional modeling. In response to a user's operation, the three-dimensional modeling apparatus adds data for modeling the support column to three-dimensional modeling data for modeling a three-dimensional product in accordance with the shape of the three-dimensional product. The support column is preferably arranged for the three-dimensional product in view of being removed from the three-dimensional product. However, it is a cumbersome task for a designer to arrange a support column for a three-dimensional product considering that the support column is removed from the three-dimensional product.

[0005] The present invention provides a data generation program and a modeling system capable of generating three-dimensional modeling data for modeling a three-dimensional product and a support column connecting to the three-dimensional product by using a three-dimensional modeling apparatus, considering that the support column is removed from the three-dimensional product.

SOLUTION TO PROBLEM

[0006] A data generation program according to a first aspect of the present invention includes instructions for causing a controller of a computer to perform: a data acquisition step of acquiring three-dimensional data representing a three-dimensional shape of a three-dimensional product; a condition acquisition step of acquiring an arrangement condition for arranging a support column to the three-dimensional product, the support column being connected to the three-dimensional product; a direction setting step of setting an extending direction, a width direction, and a height direction of the support column; a cutting-margin addition step of adding a cutting margin of a particular thickness to a cutting surface of the three-dimensional product at one side in the height direction; a support-column setting step of setting the support column in accordance with the arrangement condition, the support column extending in the extending direction, one end of the support column in the extending direction being connected to the cutting margin added to the three-dimensional product; a beam setting step of setting a beam, the beam being spaced from the three-dimensional product having the cutting margin in the extending direction, the beam extending in the width direction, the beam being connected to an other end of the support column in the extending direction; a modeling-data generation step of generating three-dimensional modeling data for modeling a modeled object by using a three-dimensional modeling apparatus, the modeled object including the three-dimensional product, the cutting margin, the support column, and the beam; and an output step of outputting the three-dimensional modeling data.

[0007] According to the data generation program of the first aspect, by executing the data generation program, the computer can generate three-dimensional modeling data for modeling the modeled object by using the three-dimensional modeling apparatus, the modeled object including the three-dimensional product, the cutting margin, the support column, and the beam. The support column extends in accordance with the arrangement condition, and the one end of the support column in the extending direction is connected to the cutting margin added to the three-dimensional product. The support column is removed together with the cutting margin by removing the cutting margin from the three-dimensional product by the cutting apparatus. Thus, it is unnecessary for a user to provide a step of removing the support column separately from a step of removing the cutting margin from the modeled object, in order to obtain a three-dimensional product from the modeled object. In other words, the data generation program can generate three-dimensional modeling data for modeling the three-dimensional product and the support column connecting to the three-dimensional product by using a three-dimensional modeling apparatus, taking into consideration that the support column is removed from the three-dimensional product.

[0008] A three-dimensional modeling system according to a second aspect of the present invention includes: a data acquisition part that acquires three-dimensional data representing a three-dimensional shape of a three-dimensional product; a condition acquisition part that acquires an arrangement condition for arranging a support column to the three-dimensional product, the support column being connected to the three-dimensional product; a direction setting part that sets an extending direction, a width direction, and a height direction of the support column; a cutting-margin addition part that adds a cutting margin of a particular thickness to a cutting surface of the three-dimensional product at one side in the height direction; a support-column setting part that sets the support column in accordance with the arrangement condition, the support column extending in the extending direction, one end of the support column in the extending direction being connected to the cutting margin added to the three-dimensional product; a beam setting part that sets a beam, the beam being spaced from the three-dimensional product having the cutting margin in the extending direction, the beam extending in the width direction, the beam being connected to an other end of the support column in the extending direction; a modeling-data generation part that generates three-dimensional modeling data for modeling a modeled object by using the three-dimensional modeling apparatus, the modeled object including the three-dimensional product, the cutting margin, the support column, and the beam; a cutting-data generation part that generates three-dimensional cutting data for cutting and removing, with a cutting apparatus, the cutting margin and the one end of the support column in the modeled object; an output part that outputs the three-dimensional modeling data and the three-dimensional cutting data; a three-dimensional modeling apparatus that models the modeled object in accordance with the three-dimensional modeling data; and a cutting apparatus that cuts the modeled object in accordance with the three-dimensional cutting data to obtain the three-dimensional product.

[0009] The three-dimensional modeling system of the second aspect has effects similar to the data generation program of the first aspect. The three-dimensional modeling system can save the time and effort of the user to generate three-dimensional cutting data separately from three-dimensional modeling data. The three-dimensional modeling system can generate the three-dimensional cutting data by using the processing necessary to generate the three-dimensional modeling data, which can simplify processing compared with a case where the three-dimensional cutting data is generated separately from three-dimensional modeling data.

BRIEF DESCRIPTION OF DRAWINGS

[0010]

FIG. 1 is a block diagram showing a configuration of a three-dimensional modeling system 9 including a 3D printer 11, a cutting apparatus 12, and a data generation apparatus 1.

FIG. 2 is a flowchart of a data generation process of a first embodiment, executed by the data generation apparatus 1.

FIG. 3 is an explanatory diagram of three-dimensional data 20, a three-dimensional product 40 represented by the three-dimensional data 20, and a setting screen 30 displayed on a display 7.

FIG. 4A is a perspective view of a modeled object 121 which is represented by three-dimensional modeling data of a specific example 1 generated by the data generation process, FIG. 4B is a perspective view of a modeled object 122 which is represented by three-dimensional modeling data of a specific example 2, and FIG. 4C is a perspective view of a modeled object 123 which is represented by three-dimensional modeling data of a specific example 3.

FIG. 5 is a flowchart of a support column setting process executed in the data generation process of the first embodiment.

FIG. 6 is an explanatory diagram showing in a matrix form a process in which four columns 71 to 74, a cutting margin 56, support columns 81 to 88, and beams 111 and 112 are sequentially set in the three-dimensional product 40 of the specific example 1 in the data generation process.

FIG. 7 is an explanatory diagram showing in a matrix form a process in which four columns 71 to 74, a cutting margin 57, support columns 91 to 98, and beam 113 and 114 are sequentially set in the three-dimensional product 40 of the specific example 2 in the data generation process.

FIG. 8 is an explanatory diagram showing in a matrix form a process in which four columns 71 to 74, a cutting margin 58, support columns 101 to 108, and beams 115 and 116 are sequentially set in the three-dimensional product 40 of the specific example 3 in the data generation process.

FIG. 9 is an explanatory diagram of a process of setting support columns in a three-dimensional product 61 in the specific example 1.

FIG. 10 is an explanatory diagram showing in a matrix form a process of setting support columns in each of the three-dimensional product 61 of the specific example 1 and a three-dimensional product 62 of the specific example 2.

FIG. 11 is an explanatory diagram of a process of temporarily setting support columns 25 and 26 in the three-dimensional product 61 of the specific example 1 using a cross section taken along line B-B in the part of S33 in FIG. 10.

FIG. 12 is an explanatory diagram of a process of temporarily setting the support columns 27 and 28 in the three-dimensional product 62 of the specific example 2 using a cross section taken along line C-C in the part of S33 in FIG. 10.

FIG. 13 is an explanatory diagram of a process for setting support columns 84 and 88 in the three-dimensional product 61 of the specific example 1 using a cross section taken along line B-B in the part of S33 in FIG. 10.

FIG. 14 is an explanatory diagram of a process for setting the support columns 91 and 95 in the three-dimensional product 62 of the specific example 2 using a cross section taken along line C-C in the part of S33 in FIG. 10.

FIG. 15 is a flowchart of a support column setting process executed in a data generation process of a second embodiment.

FIG. 16A is an explanatory view of support columns 131 to 138 set in the three-dimensional product 61 of the specific example 1 according to the data generation process of the second embodiment, and FIG. 16B is an explanatory diagram of support columns 141 to 148 set in the three-dimensional product 62 of the specific example 2 according to the data generation process of the second embodiment.

DESCRIPTION OF EMBODIMENTS

[0011] A three-dimensional modeling system 9 (hereinafter simply referred to as "system 9") in first and second embodiments of the present invention will be described with reference to the drawings. The configurations common to the systems 9 in the first and second embodiments will be described with reference to FIG. 1 and FIG. 2. As shown in FIG. 1, the system 9 includes a 3D printer 11, a cutting apparatus 12, and a data generation apparatus 1. The 3D printer 11 is an apparatus capable of modeling a three-dimensional model based on three-dimensional modeling data. The 3D printer 11 may be any known type of powder bed fusion type, directed energy type, binder jetting type, sheet lamination type, photopolymerization curing (stereolithography) type, material extrusion type, and material jetting type, and the type is not particularly limited. The cutting apparatus 12 is an apparatus capable of cutting a three-dimensional model into a particular shape by using a tool such as a cutting blade, based on three-dimensional cutting data. For example, the cutting apparatus 12 cuts a three-dimensional model by three-dimensionally moving a tool relative to the three-dimensional model.

[0012] The data generation apparatus 1 is a known personal computer, and generates the three-dimensional modeling data and the three-dimensional cutting data based on the three-dimensional data representing a shape of a three-dimensional product, by executing the data generation program described later. The data generation apparatus 1 includes a CPU 2, a ROM 3, a RAM 4, a memory (storage device) 5, an external communication interface 6, a display 7, an operation part 8, and a bus 10. The CPU 2 controls the data generation apparatus 1, and is electrically connected to the ROM 3, the RAM 4, the memory 5, the external communication interface 6, the display 7, and the operation part 8, via the bus 10. The ROM 3 stores programs such as BIOS to be executed by the CPU 2. The RAM 4 temporarily stores various types of data. The memory 5 is a nonvolatile memory, and stores programs and various setting values for use in controlling the operation of the data generation apparatus 1. The display 7 is configured to display images, and is a liquid crystal display, as an example. The operation part 8 allows to input a signal into the CPU 2 in response to the operation performed by a user. The operation part 8 is, for example, at least a keyboard, a mouse, a touch panel, or a joystick. The external communication interface 6 connects the data generation apparatus 1 to external devices such as the 3D printer 11 and the cutting apparatus 12.

[0013] The outline of the data generation process to be performed by the data generation apparatus 1 of the system 9 will be described by use of specific examples 1 to 3 shown in FIG. 3 and FIGS. 4A-4C. The specific examples 1 to 3 differ from each other in the setting of the surfaces to be cut by the cutting apparatus 12. In each of the specific examples 1 to 3, the data generation apparatus 1 generates the three-dimensional modeling data for use in modeling modeled objects 121, 122, or 123 shown in FIGS. 4A-4C, based on three-dimensional data 20 representing a three-dimensional shape of a three-dimensional product 40 shown in FIG. 3. The three-dimensional data is data generated by a three-dimensional CAD, a three-dimensional modeler, a three-dimensional scanner, and so on. The data may be in any format, for example, STL (Standard Triangulated Language), IGES (Initial Graphics Exchange Specification), STEP (Standard for the Exchange of Product model data), or AMF (Additive Manufacturing). The three-dimensional data may be generated by the data generation apparatus 1 or by an external apparatus. For example, as shown in FIG. 3, the three-dimensional product 40 is a three-dimensional model that is formed to protrude toward one side, having a particular thickness as a whole, and includes a convex surface 41, a concave surface 42, and cutouts 52, 53. The convex surface 41 has a plane part 411, a side surface 412, and an outer peripheral edge 413. The plane part 411 extends in a planar shape. The plane part 411 of the three-dimensional product 40 has holes 43 to 45 formed to penetrate in the thickness direction. The hole 43 is formed in a circular shape, and the holes 44, 45 are formed in rectangular shapes. The side surface 412 is connected to the outer periphery of the plane part 411. The side surface 412 extends in the direction of intersecting the extension surface of the plane part 411 and separating from the center of the plane part 411 as it separates farther from the plane part 411. The outer peripheral edge 413 is the edge of the side surface 412 on the side far from the plane part 411. The concave surface 42 is the surface opposite to the convex surface 41. The concave surface 42 includes a plane part 421 corresponding to the plane part 411, a side surface 422 corresponding to the side surface 412, and an inner peripheral edge 423 corresponding to the outer peripheral edge 413. The cutouts 52, 53 are the portions notched, toward the plane part 421, from the edges 413, 423 formed on the side surfaces 412, 422.

[0014] In the specific example 1 shown in FIG. 4A, the convex surface 41 of the three-dimensional product 40 is set as a cutting surface (the surface to be cut). In the specific example 1, the data generation process is performed to generate the three-dimensional modeling data for use in modeling the modeled object 121 including the three-dimensional product 40 added with a cutting margin 56, four columns 71 to 74, a plate-shaped part 75, support columns 81 to 88, and beams 111, 112. The cutting margin 56 is added in a particular thickness, on the cutting surface. The support columns 81 to 88 regulate the position of the three-dimensional product 40 during the three-dimensional modeling, especially at the time of cutting. The data generation apparatus 1 sets one ends of the support columns 81 to 88 so as to be connected to the cutting margin 56, by considering that the cutting apparatus 12 cuts and removes the support columns 81 to 88 from the three-dimensional product 40. In one example, the data generation apparatus 1 in the present embodiment sets the support columns 81 to 88 at the positions allowing that the one ends of the support columns 81 to 88 are at least partially in contact with an outer peripheral edge 66 of a three-dimensional product 61. Similarly, in the specific example 2 shown in FIG. 4B, the concave surface 42 of the three-dimensional product 40 is set as the cutting surface. In the specific example 2, the data generation process is performed to generate the three-dimensional modeling data for use in modeling the modeled object 122 including the three-dimensional product 40 added with a cutting margin 57, the four columns 71 to 74, the plate-shaped part 75, support columns 91 to 98, and beams 113, 114. In one example, the data generation apparatus 1 sets the support columns 91 to 98 at the positions allowing that one ends of the support columns 91 to 98 are at least partially in contact with an outer peripheral edge 67 of a three-dimensional product 62. In the specific example 3 shown in FIG. 4C, both the convex surface 41 and the concave surface 42 of the three-dimensional product 40 are set as the cutting surfaces, and the convex surface 41 is cut finally. In the specific example 3, the data generation process is performed to generate the three-dimensional modeling data for use in modeling the modeled object 123 including the three-dimensional product 40 added with a cutting margin 58, the four columns 71 to 74, the plate-shaped parts 75 to 77, support columns 101 to 108, and beams 115, 116. In one example, the data generation apparatus 1 sets the support columns 101 to 108 at the positions allowing that one ends of the support columns 101 to 108 are at least partially in contact with an outer peripheral edge 68 of a three-dimensional product 63.

[0015] The data generation process to be performed by the CPU 2 of the data generation apparatus 1 in the first embodiment will be described by use of the specific examples 1 to 3, with reference to FIG. 2 to FIG. 14. The data generation process is started, when an instruction to start the process via the operation part 8 is detected in the state where the three-dimensional data 20 to be processed is specified, and subsequently when the CPU 2 reads a program stored in the memory 5 into the RAM 4 and executes the program. Although the data generation process is performed at different timing in the specific examples 1 to 3, the processing to be performed in the examples will be described in parallel for the sake of simplicity of description. In the following description, when a three-dimensional model (for example, support column) is added or set for the three-dimensional product 40, the three-dimensional data representing the three-dimensional shape of the set three-dimensional model may be added to the three-dimensional data 20 of the three-dimensional product 40, or may be generated separately from the three-dimensional data 20 and stored in association with the three-dimensional data 20. The various set values to be referred to in the data generation process may be set in advance, may be automatically set from among multiple types of values according to the shape, the size and so on of the three-dimensional product 40, or may be set by a user via the operation part 8.

[0016] As shown in FIG. 2, the CPU 2 acquires the three-dimensional data 20 representing the three-dimensional shape of the three-dimensional product 40 (S1). In one example, the CPU 2 acquires the three-dimensional data 20 in an STL format schematically shown in FIG. 3 from an external device by wire or wireless communication. The three-dimensional data 20 in the STL format includes the three-dimensional coordinate data of the vertexes of a group of triangles representing the three-dimensional shape of the three-dimensional product 40.

[0017] The CPU 2 displays, on the display 7, a setting screen 30 (refer to FIG. 3) related to the three-dimensional data 20 acquired in S1 (S2). As shown in FIG. 3, the setting screen 30 includes fields 31 to 35 and a key 36. The field 31 displays the three-dimensional shape of the three-dimensional product 40 based on the three-dimensional data 20 acquired in S1. The CPU 2 initially displays, in the field 31, the three-dimensional shape of the three-dimensional product 40 by setting the X direction, the Y direction and the Z direction in the three-dimensional data 20 as a left-right direction, a front-rear direction, and an upper-lower direction, respectively. The positive X side, the positive Y side and the negative

Z side correspond to the right side, the rear side and the upper side, respectively. The field 32 displays the overall sizes of the three-dimensional product 40 in the X direction, the Y direction and the Z direction based on the three-dimensional data 20 acquired in S1. In the field 33, the single-side/double-side setting is specified. The single-side/double-side setting is a setting for whether one side face in the height direction of the modeled object is set as the cutting surface (single-side), or both of one side face and the other side face in the height direction of the modeled object are set as the cutting surface (double-side) when the modeled object modeled by the 3D printer 11 is to be cut by the cutting apparatus 12. The single-side/double-side setting is selectively performed in a radio button. In the single-side/double-side setting, the single-side is set as the default. The one side and the other side in the height direction of the modeled object are set based on the final cutting surface that is finally cut by the cutting apparatus 12. The field 34 is a field for setting the final cutting surface. The final cutting surface is selectable from among the surface on the positive X side, the surface on the negative X side, the surface on the positive Y side, the surface on the negative Y side, the surface on the positive Z side, and the surface on the negative Z side. The surface on the positive Z side is set as the default. The field 35 is a field for specifying rotation about the Z axis. The field 35 is used to input the rotation angle at which the three-dimensional product 40 displayed in the field 31 rotates about the Z axis. The key 36 is operated to confirm and instruct the setting of conditions performed in the setting screen 30. In S3 to S9, the CPU 2 performs the processes of accepting changes in various types of settings via the setting screen 30.

[0018] The CPU 2 determines whether the operation of the key 36 has been detected, based on the output by the operation part 8 (S3). When the operation of the key 36 has not been detected (S3: NO), the CPU 2 determines whether the selection in the setting of the final cutting surface in the field 34 has been detected, based on the output by the operation part 8 (S4). When the selection in the setting of the final cutting surface has been detected (S4: YES), the CPU 2 sets the final cutting surface based on the output by the operation part 8 and changes the three-dimensional shape displayed in the field 31 such that the final cutting surface faces upward (S5), and thereafter returns the processing to S3. In the specific examples 1, 3, the convex surface 41 is set as the final cutting surface. In the specific example 2, the concave surface 42 is set as the final cutting surface. When the selection in the setting of the final cutting surface has not been detected (S4: NO), the CPU 2 determines whether the selection in the single-side/double-side setting in the field 33 has been detected, based on the output by the operation part 8 (S6). When the selection in the single-side/double-side setting has been detected (S6: YES), the CPU 2 sets single-side or double-side based on the output by the operation part 8 (S7), and thereafter returns the processing to S3. In the specific examples 1 and 2, single-side is set in the single-side/double-side setting. In the specific example 3, double-side is set in the single-side/double-side setting. When the selection in the single-side/double-side setting has not been detected (S6: NO), the CPU 2 determines whether an instruction of the rotation about the Z axis in the field 35 has been detected, based on the output by the operation part 8 (S8). When an instruction of the rotation about the Z axis has been detected (S8: YES), the CPU 2 rotates the three-dimensional product 40 displayed in the field 31, about the Z axis by the rotation angle inputted in the field 35, and changes the three-dimensional product 40 displayed in the field 31 according to the result of the rotation (S9), and thereafter returns the processing to S3. When no instruction of the rotation about the Z axis has been detected (S8: NO), the CPU 2 returns the processing to S3.

[0019] When in S3 the operation of the key 36 has been detected (S3: YES), the CPU 2 generates three-dimensional modeling data and three-dimensional cutting data based on the settings in the setting screen 30, and performs the processing of outputting the generated data. Specifically, the CPU 2 sets a new Z axis based on the setting in the setting screen 30 (S10). The CPU 2 sets the final cutting surface set in the field 34, to the new positive Z direction. The CPU 2 sets a new X axis and a new Y axis (S11). The CPU 2 sets, as the new X axis and the new Y axis, the longitudinal direction and the short direction, respectively, of the projected figure that is acquired when the three-dimensional product 40 is projected from the positive Z direction set in S11 onto the imaginary XY plane perpendicular to the Z axis. The CPU 2 performs the conversion of the three-dimensional data acquired in S1, based on the X axis, the Y axis and the Z axis newly set in S10 and S11. In the specific examples 1, 3, the X axis, the Y axis and the Z axis are set as shown in the row of S11 in FIG. 6. In the specific example 2, the X axis, the Y axis and the Z axis are set as shown in the row of S11 in FIG. 7. In each of FIG. 6 to FIG. 8, the plan view shows the object viewed from the positive Z side; the right side view shows the object viewed from the positive X side; and the left side view shows the object viewed from the negative X side.

[0020] The CPU 2 sets the four columns 71 to 74 for the three-dimensional product 40, based on the three-dimensional data converted according to the new X axis, the new Y axis, and the new Z axis (S12). The four columns 71 to 74 are disposed apart from the three-dimensional product 40 so as to extend in the Z direction, and are used to position the three-dimensional product 40 at the time of the three-dimensional modeling by the 3D printer 11. The CPU 2 uses, for example, the following procedure to set the four columns 71 to 74 for the three-dimensional product 40. The CPU 2 defines a smallest rectangular parallelepiped J that circumscribes the three-dimensional product 40, based on the minimum value of the X coordinate, the maximum value of the X coordinate, the minimum value of the Y coordinate, the maximum value of the Y coordinate, the minimum value of the Z coordinate, and the maximum value of the Z coordinate of the converted three-dimensional data. The rectangular parallelepiped J has two planes parallel to the XY plane, two planes parallel to the YZ plane, and two planes parallel to the ZX plane. The CPU 2 sets, as the positions of the center axes of the columns, the points which are away from four vertexes P1 to P4 on a plane parallel to the XY plane in the directions away from the center of the three-dimensional product 40, by a particular distance D1 in the X direction and a particular distance D2 in the Y direction, respectively. The coordinates (X, Y) of the four vertexes P1 to P4 are respectively (the minimum value of the X coordinate, the minimum value of the Y coordinate), (the minimum value of the X coordinate, the maximum value of the Y coordinate), (the maximum value of the X coordinate, the minimum value of the Y coordinate), and (the maximum value of the X coordinate, the maximum value of the Y coordinate). The coordinates (X, Y) of the center axes corresponding to the four vertexes P1 to P4 are respectively (the value acquired by subtracting D1 from the minimum value of the X coordinate, the value acquired by subtracting D2 from the minimum value of the Y coordinate), (the value acquired by subtracting D1 from the minimum value of the X coordinate, the value acquired by adding D2 to the maximum value of the Y coordinate), (the value acquired by adding D1 to the maximum value of the X coordinate, the value acquired by subtracting D2 from the minimum value of the Y coordinate), and (the value by adding D1 to the maximum value of the X coordinate, the value acquired by adding D2 to the maximum value of the Y coordinate). The CPU 2 sets, as the extension range in the Z direction of the four columns 71 to 74, the range from the coordinate which is smaller by a particular value D3 than the minimum value of the Z coordinate of the three-dimensional product 40 (the value acquired by subtracting D3 from the minimum value of the Z coordinate) to the coordinate which is larger by a particular value D4 than the maximum value of the Z coordinate of the three-dimensional product 40 (the value acquired by adding D4 to the maximum value of the Z coordinate). The CPU 2 sets, as the four columns 71 to 74, the circular columns so as to extend in the set extension range in the Z direction and have a particular radius with the set center axes. The shape, the arrangement, the size, the extension range, and so on, of the columns 71 to 74 set in S12 may be changed as appropriate.

[0021] The CPU 2 sets a processing origin (S13). The processing origin is the machine origin serving as the reference used when the 3D printer 11 models the modeled object, and also the machine origin serving as the reference used when the cutting apparatus 12 cuts the modeled object. The processing origin for the 3D printer 11 and the processing origin for the cutting apparatus 12 may be different from each other. For example, the CPU 2 sets, as the processing origin, the position of the column 71 set in the negative X direction and the negative Y direction with respect to the three-dimensional product 40, among the positions of the four columns 71 to 74 set in S12. The CPU 2 determines whether single-side has been set in the single-side/double-side setting (S14). In the specific examples 1 and 2, it is determined that single-side has been set in the single-side/double-side setting (S14: YES). As shown in the row of S16 in FIG. 6, in the specific example 1, the CPU 2 adds the plate-shaped part 75, as the mark of the processing origin, to the column 71 (the column set in the negative X direction and the negative Y direction among the four columns 71 to 74) in the three-dimensional product 40 (S15). The plate-shaped part 75 has a particular length in the positive X direction and a particular width in the positive Y direction from the center axis of the column 71. The CPU 2 adds the cutting margin 56 having a particular thickness to the entirety of the convex surface 41 which serves as the cutting surface on the positive Z side of the three-dimensional product 40 (S16). In the specific example 1, the three-dimensional product 40 to which the cutting margin 56 is added is simply referred to as the three-dimensional product 61, and the outer peripheral edge 413 to which the cutting margin 56 is added is simply referred to as the outer peripheral edge 66. Similarly, in the specific example 2, as shown in the row of S16 in FIG. 7, the CPU 2 adds the plate-shaped part 75 to the column 71 among the columns 71 to 74 (S15), and adds the cutting margin 57 having a particular thickness to the entirety of the concave surface 42 and the surface between the inner peripheral edge 423 and the outer peripheral edge 413 (S16). In the specific example 2, the three-dimensional product 40 to which the cutting margin 57 is added is simply referred to as the three-dimensional product 62, and the outer peripheral edge 413 to which the cutting margin 57 is added is simply referred to as the outer peripheral edge 67.

[0022] In the specific example 3, the CPU 2 determines that double-side has been set in the single-side/double-side setting (S14: No). As shown in the row of S18 in FIG. 8, the CPU 2 adds the plate-shaped parts 75 and 76, as the mark of the processing origin, to the column 71 (the column set in the negative X direction and the negative Y direction among the four columns 71 to 74) in the three-dimensional product 40 (S17). The plate-shaped part 75 has a particular length in the positive X direction and a particular width in the positive Y direction from the center axis of the column 71. The plate-shaped part 76 has a particular length in the positive X direction and a particular width in the negative Y direction from the center axis of the column 71. The CPU 2 further adds the plate-shaped part 77 to the column 72 (the column set in the negative X direction and the positive Y direction) in the three-dimensional product 40. The plate-shaped part 77 has a particular length in the positive X direction and a particular width in the negative Y direction from the center axis of the column. The CPU 2 adds the cutting margin 58 having a particular thickness to the surfaces to be cut on the positive Z side and the negative Z side of the three-dimensional product 40, that is, to the entirety of the convex surface 41 and to the entirety of the concave surface 42 (S18). In the specific example 3, the three-dimensional product 40 to which the cutting margin 58 is added is simply referred to as the three-dimensional product 63, and the outer peripheral edge 413 to which the cutting margin 58 is added is simply referred to as the outer peripheral edge 68. As described above, in the present embodiment, one of the cutting margins 56 to 58 having particular thicknesses is added to the outer peripheral edge 413 of the three-dimensional product 40, depending on whether the cutting surface of the three-dimensional product 40 is the convex surface 41, the concave surface 42, or both the convex surface 41 and the concave surface 42.

[0023] After S16 or S18, the CPU 2 performs a support column setting process (S19). In the support column setting process, a support column formed to extend in an extending direction according to arrangement conditions is set such that one end of the support column in the extending direction is connected to the cutting margin added to the three-dimensional product 40. The support column setting process in the specific examples 1 and 2 will be described with reference to FIG. 5 and FIG. 9 to FIG. 14. The support column setting process in the specific example 3 is the same as the processing in the specific example 1, and the description thereof is thus omitted. As shown in FIG. 5, the CPU 2 acquires the arrangement conditions indicating under what conditions the support columns are arranged for the three-dimensional product 61 or 62 (S30). The arrangement conditions may be set in advance, may be set automatically according to the shape, the size and so on of the three-dimensional product 61 or 62, or may be set by a user. The arrangement conditions in the present embodiment are set automatically, regardless of the shape, the size and so on of the three-dimensional product 61 or 62, and include a width Q in the width direction of the support column, a height H in the height direction of the support column, and a pitch P in the width direction which is a distance corresponding to an interval between adjacent support columns. The pitch P in the width direction of adjacent support columns is set by considering the width in the width direction of adj acent support columns. When set without considering the width in the width direction of adj acent support columns, the pitch P may be an interval in the width direction of adjacent support columns. The CPU 2 sets the width direction and the extending direction of the support columns (S31). The width direction and the extending direction of the support columns may be automatically set according to the shape, the size and so on of the three-dimensional product 40, or may be set by a user. The CPU 2 in the present embodiment automatically sets the X, Y, and Z directions based on the XYZ coordinate system set in S10 and S11. That is, the X direction is the extending direction of the support columns, the Y direction is the width direction of the support columns, and the Z direction is the height direction of the support columns.

[0024] The CPU 2 sets, according to the arrangement conditions acquired in S30, the extension ranges in the width direction of the support columns set for the three-dimensional product 61 or 62 (S32). In the specific example 1, as shown in FIG. 9 and in the row of S33 in FIG. 10, the CPU 2 sets extension ranges R1 to R4 of the support columns according to an equation (1). Here, a center D in the Y direction of the three-dimensional product 61 is used as a reference; a distance E is the distance between the center D and the support column adjacent to the center D; the pitch P is the distance in the width direction of adjacent support columns; and the width Q is the width in the width direction of the support columns. The variables in the equation (1) are set so as to satisfy an equation (2). The value of n in the equations 1 and 2 is an integer.

$$\text{Equation (1):}\quad Y = D \pm E,\ D \pm (E + P\times n)$$

$$\text{Equation (2):}\quad \text{Maximum size of three-dimensional product in Y direction}/2 > (E + P\times n + Q)$$

The extension ranges R1 to R4 for the three-dimensional product 61 are set in the order from the positive Y direction side. Similarly, in the specific example 2, as shown in the row of S33 in FIG. 10, the CPU 2 sets the extension ranges R1 to R4 of the support columns. The CPU 2 sets 1 as a variable N (S33). The variable N is used to read out the extension ranges R1 to R4 of the support columns set in S33 in the order from the range on the positive Y side. The CPU 2 sets the positive extending direction as a setting direction, and sets the maximum value in the extending direction as a coordinate condition (S34). The setting direction is the extending direction of the support columns for the three-dimensional product 61, 62. The coordinate condition is a condition for identifying the outer peripheral edge 66, 67 of the three-dimensional product 61, 62. When the setting direction is the positive extending direction, the coordinate condition is the maximum value in the extending direction. When the setting direction is the negative extending direction, the coordinate condition is the minimum value in the extending direction.

[0025] The CPU 2 identifies the maximum value of the Y coordinate in the extension range of the Nth support column as the coordinate of one end in the width direction in the extension range of the Nth support column, and sets 1 as a variable M (S35). The variable M is used to read out ranges obtained by dividing each of the extension ranges R1 to R4 set in S33 by a width K into a plurality of ranges, in the order from the range on the positive Y side. In one example, as shown in FIG. 9, the CPU 2 in the present embodiment divides each of the extension ranges R1 to R4 by the width K into ten ranges, and reads out ranges U1 to U10 in this order. The CPU 2 sets the Mth range in the extension range of the Nth support column, according to the coordinate identified in S35, the variable M, and the width K (S36). In the specific example 1, when the variable N is 1 and the variable M is 1, the range U1 shown in FIG. 9 is set as the Mth range in the extension range of the Nth support column. In the specific example 1, the CPU 2 identifies the outer peripheral edge 66 of the three-dimensional product 61 in the range set in S36 according to the coordinate condition set in S34 or S48. In the specific example 2, the CPU 2 identifies the outer peripheral edge 67 of the three-dimensional product 61 in the range set in S36 according to the coordinate condition set in S34 or S48 (S37). The row of S37 of the specific example 1 in FIG. 10 shows a cross-sectional view of the specific example 1 taken along a B-B line shown in the row of S33, viewed from the direction of the arrow. The row of S37 of the specific example 2 shows a cross-sectional view of the specific example 2 taken along a C-C line shown in the row of S33, viewed from the direction of the arrow. In the specific example 1, when the variable N is 4 and the variable M is 1, as shown in the row of S37 of the specific example 1 in FIG. 10, the CPU 2 identifies a point Xmax having the maximum value of the X coordinate of the three-dimensional product 61, as the coordinate of the outer peripheral edge 66 in the range set in S36, and stores the point Xmax in association with the variable N and the variable M. Similarly, in the specific example 2, when the variable N is 1 and the variable M is 10, as shown in the row of S37 of the specific example 2 in FIG. 10, the CPU 2 identifies the point Xmax having the maximum value of the X coordinate of the three-dimensional product 62, as the coordinate of the outer peripheral edge 67 in the range set in S36, and stores the point Xmax in association with the variable N and the variable M. The CPU 2 determines whether the Mth range set in S36 includes the other end in the width direction in the extension range of the Nth support column (S38). When the variable M is 10, the CPU 2 in the present embodiment determines that the Mth range includes the other end in the width direction in the extension range of the Nth support column. When the set Mth range does not include the other end in the width direction in the extension range of the Nth support column (S3 8: NO), the CPU 2 increments the variable M by 1 (S39), and thereafter returns the processing to S36. The repeated execution of S37 allows to acquire ten coordinates respectively corresponding to the ranges U1 to U10 for the extension range of the Nth support column.

[0026] When the set Mth range includes the other end in the width direction in the extension range of the Nth support column (S3 8: YES), the CPU 2 temporarily sets the Nth support column that extends in the setting direction set in S34, within the extension range of the Nth support column, for the three-dimensional product 61 or 62 (S40). The CPU 2 temporarily sets the Nth support column that extends in the setting direction for the three-dimensional product 61 or 62 in accordance with the following procedure, for example. As shown in FIG. 11, when the variable N is 4 in the specific example 1, the CPU 2 sets a point F which is separated from the point Xmax having the maximum value in the X direction by a particular distance G in the negative X side and separated by a height H in the positive Z side, with respect to each of the plurality of coordinates identified in S37. The CPU 2 sets the extension range in the height direction of the support column (the extension range in the Z direction) from the point Xmax to the point F, and sets the extension range in the extending direction (the extension range in the Z direction) from the point F to the center axes of the columns 73, 74 positioned in the positive X side with respect to the three-dimensional product 61. The CPU 2 temporarily sets, to the three-dimensional product 61, the three-dimensional model extending in the extension range in the extending direction, the extension range in the height direction of the support column, and the extension range in the width direction of the support column set in S32, as a fourth support column 25 of the specific example 1 that extends in the setting direction. Similarly, as shown in FIG. 12, when the variable N is 1 in the specific example 2, the CPU 2 temporarily sets, to the three-dimensional product 62, the three-dimensional model extending in the extension range in the extending direction of the support column, the extension range in the height direction of the support column, and the extension range in the width direction set in S32, as a first support column 27 of the specific example 2 that extends in the setting direction.

[0027] The CPU 2 determines whether there is an intersection between the three-dimensional product 61 and the positive Z-side surface of the support column 25, 27 temporarily set in S40 (S41). When there is an intersection as in the support column 25 of the specific example 1 (S41: YES), the CPU 2 performs a process of setting a support column on the convex surface 41 (S42). Specifically, as shown in FIG. 13, the CPU 2 identifies the intersection surface where the support column 25 temporarily set in S40 and the three-dimensional product 61 intersect each other, changes the end on the negative X side of the support column 25 temporarily set in S40 to the identified intersection surface, and sets the Nth support column 84 that extends in the setting direction set in S34 to the three-dimensional product 61. In other words, the support column 84 is set such that the end on the negative X side of the support column 84 is connected to the cutting margin 56 of the three-dimensional product 61. When there is no intersection as in the support column 27 of the specific example 2 (S41: NO), the CPU 2 performs a process of setting a support column on the concave surface 42 (S43). Specifically, as shown in FIG. 14, the CPU 2 identifies the intersection surface where the support column 27 temporarily set in S40 and the three-dimensional product 62 intersect each other, changes the end on the negative X side of the support column 27 temporarily set in S40 to the identified intersection surface, and sets the first support column 91 that extends in the setting direction set in S34, to the three-dimensional product 62. If there is no intersection where the support column 27 temporarily set in S40 and the three-dimensional product 62 intersect each other, the CPU 2 extends the negative Z-side surface of the support column 27 temporarily set in S40 to the position at which the support column 27 makes contact with the three-dimensional product 62, toward the negative Z side.

[0028] After the process of S42 or S43, the CPU 2 determines whether the setting direction is the positive extending direction (S44). When the setting direction is the positive extending direction (S44: YES), the CPU 2 sets the negative extending direction as the setting direction, and sets the minimum value in the extending direction as the coordinate condition (S48), and thereafter returns the processing to S35 to perform the processing of setting the Nth support column that extends in the negative extending direction to the three-dimensional product 61, 62 (from S35 to S43).

[0029] In the process of S37 of setting the Nth support column that extends in the negative extending direction to the three-dimensional product 61, 62, as shown in the row of S37 in FIG. 10, in the specific example 1, 2, the CPU 2 identifies a point Xmin having the minimum value of the X coordinate in the three-dimensional product 61, 62 as the coordinate of the outer peripheral edge 66, 67 in the range set in S36, and stores the point Xmin in association with the variable N and the variable M. In the specific example 1, as shown in FIG. 11, the CPU 2 temporarily sets a support column 26 (S40). As shown in FIG. 13, the CPU 2 identifies the intersection surface where the support column 26 temporarily set in S40 and the three-dimensional product 61 intersect each other, changes the end on the positive X side of the support column 26 temporarily set in S40 to the identified intersection surface, and sets the fourth support column 88 that extends in the setting direction set in S48, to the three-dimensional product 61 (S42). In other words, the support column 88 is set such that the end on the positive X side of the support column 88 is connected to the cutting margin 56 of the three-dimensional product 61. In the specific example 2, as shown in FIG. 12, the CPU 2 temporarily sets a support column 28 (S40). As shown in FIG. 14, since there is no other intersection than the point Xmin where the support column 28 temporarily set in S40 and the three-dimensional product 62 intersect each other, the CPU 2 extends the negative Z-side surface of the support column 28 temporarily set in S40 to the position where the support column 28 makes contact with the three-dimensional product 62 on the negative Z side, and sets the first support column 95 that extends in the setting direction set in S48, to the three-dimensional product 62 (S42). In other words, the support column 95 is set such that the negative Z-side surface of the end on the positive X side of the support column 95 is connected to the cutting margin 57 of the three-dimensional product 62.

[0030] When the setting direction is the negative extending direction (S44: NO), the CPU 2 determines whether the variable N is the number of the extension ranges set in S32 (S46). In the specific examples 1, 2, when the variable N is not 4 (S46: NO), the CPU 2 increments the variable N by 1 (S47), and thereafter returns the processing to S34. When the variable N is 4 (S46: YES), the support column setting process by the CPU 2 is completed by the processing above, and the CPU 2 returns the processing to the data generation process shown in FIG. 2. The support column setting process is performed to set, in the specific example 1, the support columns 81 to 88 formed to extend in the X direction as the longitudinal directions thereof, as shown in the row of S19 in FIG. 6. Each of the positive Z-side surfaces and the negative Z-side surfaces of the support columns 81 to 84 is curved or inclined according to the shape of the outer peripheral edge 66. Each of the positive Z-side surfaces and the negative Z-side surfaces of the support columns 85 to 88 is formed to extend in parallel to the XY plane according to the shape of the outer peripheral edge 66. Similarly, in the specific example 2, as shown in the row of S19 in FIG. 7, the support columns 91 to 98 are set so as to extend in the X direction as the longitudinal directions thereof. In the specific example 3, as shown in the row of S19 in FIG. 8, the support columns 101 to 108 are set so as to extend in the X direction as the longitudinal directions thereof.

[0031] The CPU 2 sets beams for the three-dimensional product 61 to 63 (S20). As shown in the row of S20 in FIG. 6, in the specific example 1, the beams 111, 112 for the three-dimensional product 61 are set so as to be separated from the three-dimensional product 61 in the extending direction of the support columns 81 to 88, and formed to extend in the width direction of the support columns 81 to 88 so as to be connected to the other ends of the support columns 81 to 88 on the sides far from the three-dimensional product 61 of the both ends in the extending direction. In the present embodiment, both ends of the beam 111 in the Y direction are connected to the columns 73, 74 set in S12, and both ends of the beam 112 in the Y direction are connected to the columns 71, 72 set in S12. The CPU 2 performs the following procedure to set the beams 111, 112. The CPU 2 sets the extension ranges in the X direction and the Y direction of the beams 111, 112, based on the four columns 71 to 74 set in S12. The CPU 2 sets the end in the negative X direction of the extension range in the X direction of the beam between the columns 71, 72 at the position separated from the centers in the X direction of the columns 71, 72 by a distance D5 in the negative X direction. The distance D5 is longer than zero, and shorter than the radius of the columns 71, 73. The CPU 2 sets the end in the positive X direction of the extension range in the X direction of the beam 112 between the columns 71, 72, at the position of the ends in the positive X direction of the columns 71, 72. Similarly, the CPU 2 sets the end in the positive X direction of the extension range in the X direction of the beam 111 between the columns 73, 74, at the position separated from the centers in the X direction of the columns 73, 74, by the distance D5 in the negative X direction. The CPU 2 sets the end in the negative X direction of the extension range in the X direction of the beam 111 between the columns 73, 74, at the position of the end in the negative X direction of the columns 71, 72.

[0032] The CPU 2 sets the extension range in the Z direction of the beam 111 from the minimum value to the maximum value in the Z direction of the support columns 81 to 84 connected to the beam 111. The CPU 2 sets the extension range in the Z direction of the beam 112 from the minimum value to the maximum value in the Z direction of the support columns 85 to 88 connected to the beam 112. The CPU 2 sets the beams 111, 112 in quadrangular prism shapes so as to extend in the Y direction as the longitudinal directions thereof, based on the set extension ranges in the X direction, the Y direction and the Z direction. In the specific example 1, the three-dimensional model including the three-dimensional product 61, the four columns 71 to 74, the plate-shaped part 75, the support columns 81 to 88, and the beams 111, 112 is also referred to as the modeled object 121. As shown in the row of S20 in FIG. 7, in the specific example 2, the beams 113, 114 are set in a similar procedure so as to extend in the Y direction as the longitudinal directions thereof. In the specific example 1, the three-dimensional model including the three-dimensional product 62, the four columns 71 to 74, the plate-shaped part 75, the support columns 91 to 98, and the beams 113, 114 is also referred to as the modeled object 122. As shown in the row of S20 in FIG. 8, in the specific example 3, the beams 115, 116 are set so as to extend in the Y direction as the longitudinal directions thereof. In the specific example 3, the three-dimensional model including the three-dimensional product 63, the four columns 71 to 74, the plate-shaped parts 75 to 77, the support columns 101 to 108, and the beams 115, 116 is also referred to as the modeled object 123.

[0033] The CPU 2 generates the three-dimensional modeling data for use in modeling the modeled object 121 to 123 by the 3D printer 11 (S21). The format of the three-dimensional modeling data may be appropriately determined according to the format for modeling by the 3D printer 11. For example, the three-dimensional modeling data in the specific example 1 includes the data for use in modeling the modeled object 121, that is, the data representing the respective three-dimensional shapes of the three-dimensional product 40, the four columns 71 to 74 set in S12, the plate-shaped part 75 serving as the marker added in S15, the cutting margin 56 added in S16, the support columns 81 to 88 set in S19, and the beams 111, 112 set in S20. The CPU 2 generates the three-dimensional cutting data for use in cutting the three-dimensional product 40 (S22). The three-dimensional cutting data represents the shape of the three-dimensional model that remains after the cutting by the cutting apparatus 12. For example, the three-dimensional cutting data in the specific example 1 includes the data representing the three-dimensional shape of the four columns 71 to 74 set in S12, the plate-shaped part 75 added in S15, and the three-dimensional product 40. The CPU 2 acquires the difference between the three-dimensional modeling data generated in S21 and the three-dimensional cutting data generated in S22 (S23). For example, in the specific example 1, the CPU 2 acquires the data representing the respective three-dimensional shapes of the cutting margin 56 added in S16, the support columns 81 to 88 set in S19, and the beams 111, 112 set in S20. The CPU 2 generates NC data for use in cutting the modeled object 121 to 123 by the cutting apparatus 12, based on the difference acquired in S23 (S24). For example, in the specific example 1, the CPU 2 generates NC data for use in cutting and removing, from the modeled object 121, the cutting margin 56 added in S16, the support columns 81 to 88 set in S19, and the beams 111, 112 set in S20 which are included in the difference acquired in S23. The CPU 2 outputs the three-dimensional modeling data generated in S21 to the 3D printer 11, and outputs the NC data for the cutting apparatus 12 generated in S24 to the cutting apparatus 12 (S25). The data generation process by the CPU 2 is completed by the processing above. In the system 9, the 3D printer 11 performs a process of modeling the modeled object 121 to 123 based on the three-dimensional modeling data outputted by the data generation apparatus 1. The cutting apparatus 12 performs cutting and processing on the modeled object 121 to 123 modeled by the 3D printer 11 based on the NC data for the cutting apparatus 12 outputted by the data generation apparatus 1, thereby creating the three-dimensional product 40 of which the surfaces to be cut have been cut.

[0034] In the data generation process in the first embodiment described above, in the specific example 1, the support columns 81 to 88 are set along the shape of the outer peripheral edge 66 of the three-dimensional product 61. In the data generation process of a second embodiment, support columns having a particular XZ cross-sectional shape are set at positions identified by the outer peripheral edge 66 of the three-dimensional product 61. The data generation process of the second embodiment will be described with reference to FIGS. 15, 16A and 16B. The data generation process in the second embodiment and the data generation process in the first embodiment differ from each other in the support column setting process of S19, and are the same with respect to other processing. In FIG. 15, the steps in the support column setting process which are the same as the steps in the first embodiment shown in FIG. 5 are indicated with the same step numbers. As shown in FIG. 15, the support column setting process of the first embodiment differs from the support column setting process of the first embodiment, in that the steps from S51 to S56 instead of the steps from S35 to S43 are performed. The other steps in the support column setting process are the same as those in the support column setting process of the first embodiment. The same steps as those in the support column setting process of the first embodiment will not be described or will be described simply herein, and the steps from S51 to S56 different from the steps in the support column setting process of the first embodiment will be described by use of the similar specific examples 1, 2 in the first embodiment.

[0035] The CPU 2 acquires the extension ranges of the Nth support column set in S33 (S51). The CPU 2 identifies a representative outer peripheral edge part of the outer peripheral edge 66, 67 in the extension ranges of the Nth support column acquired in S51, according to a particular condition (S52). The particular condition may be set as appropriate. For example, the coordinate which satisfies the coordinate condition of a representative point such as of one end, the other end, or the center in the Y direction of the extension ranges of the Nth support column acquired in S51 may be specified as the representative outer peripheral edge part. The coordinate which satisfies the coordinate condition of the extension ranges of the Nth support column acquired in S51 may be specified as the representative outer peripheral edge part. In one example, the CPU 2 identifies, as the representative outer peripheral edge part, the point having a larger Z coordinate value from among the point of one end in the Y direction on the coordinate satisfying the coordinate condition and the point of the other end in the Y direction on the coordinate satisfying the coordinate condition, in the extension range of the Nth support column acquired in S51.

[0036] The CPU 2 temporarily sets, to the three-dimensional product 61 or 62, the Nth support column extending in the setting direction set in S34 or S48 as in the first embodiment, based on the representative outer peripheral edge part set in S52, the condition of the position specified by the representative outer peripheral edge part, the condition of the XZ cross-sectional shape, and the arrangement conditions set in S30 (S53). The condition of the position identified by the representative outer peripheral edge part may be set as appropriate according to the identification condition of the representative outer peripheral edge part, and is, for example, a position at which at least a part of one end of the support column in the extending direction is in contact with the representative outer peripheral edge part identified in S52. As the condition of the XZ cross-sectional shape, for example, any of rectangular, circular, elliptical, and polygonal shapes may be used. The respective conditions may be set by a user, or set in advance. For example, when the representative outer peripheral edge part is the point of the end in the positive Y direction in the extension range of the Nth support column, the CPU 2 sets the quadrangular prism support column having the rectangular shape in the XZ cross-sectional shape, in which the representative outer peripheral edge part is positioned at the vertex of the negative Z side and the positive Y side. The CPU 2 sets the position of the end on the opposite side of the setting direction of the Nth support column, as in S40 of the first embodiment.

[0037] The CPU 2 determines whether there is an intersection between the three-dimensional product 61 or 62 and any of the two sides extending in the X direction on the positive Z side, of the Nth support column formed in the quadrangular prism shape set in S53 (S54). In the specific example 1, the CPU 2 determines that there is an intersection (S54: YES), and the CPU 2 performs a process of setting a support column on the convex surface 41 (S55). The CPU 2 sets a support column such that at least a part of one end on the side of the three-dimensional product 61 of the support column in the extending direction is connected to the cutting margin 56 of the three-dimensional product 61. The CPU 2 identifies the intersection surface where one end of the support column temporarily set in S53 in the extending direction intersects the three-dimensional product 61, and changes the one end of the support column temporarily set in S53 in the extending direction to the identified intersection surface. The CPU 2 maintains the temporarily set condition for the part not intersecting the three-dimensional product 61, of the one end of the support column temporarily set in S53 in the extending direction. In the specific example 1, the support column setting process is performed to set support columns 131 to 138 as shown in FIG. 16A. The support columns 135 to 138 are formed to extend from the side surface on the negative X direction of the three-dimensional product 61 toward the negative X direction, and are not visible from the positive X direction. Accordingly, in FIG. 16A, the positions in the Z direction and the Y direction of the support columns 135 to 138 are indicated with virtual lines. The surfaces on the positive Z side and the surfaces on the negative Z side of the support columns 131 to 138 are parallel to the XY plane, regardless of the shape of the outer peripheral edge 66 of the three-dimensional product 61. In the specific example 2, the CPU 2 determines that there is no intersection (S54: NO), and the CPU 2 performs a process of setting a support column on the concave surface 42 (S56). The processing as in S43 in the first embodiment is performed to set support columns 141 to 148 as shown in FIG. 16B. The surfaces on the positive Z side and the surfaces on the negative Z side of the support columns 141 to 148 are parallel to the XY plane, regardless of the shape of the outer peripheral edge 67 of the three-dimensional product 62.

[0038] In the data generation apparatus 1 and the system 9 of the first and second embodiments, the data generation apparatus 1, the CPU 2, the 3D printer 11, and the cutting apparatus 12 are examples of the computer, the controller, the three-dimensional modeling apparatus, and the cutting apparatus of the present invention, respectively. The processing of S1 is an example of a data acquisition step of the present invention. The processing of step S30 is an example of a condition acquisition step of the present invention. S31 and S32 are examples of a direction setting step of the present invention. The processing of S42, S43, S55, and S56 is an example of a support column setting step of the present invention. The processing of S20 is an example of a beam setting step of the present invention. The processing of S21 is an example of a modeling data generation step of the present invention. The processing of S25 is an example of an output step of the present invention. The processing of S22 and S24 is an example of a cutting data generation step of the present invention. The processing of S4 and S6 is an example of a reception step of the present invention. The processing of S37 and S52 is an example of an edge identifying step of the present invention.

[0039] The effects of the data generation program and the system 9 of the first and second embodiments described above will be described mainly using the specific example 1 of the first embodiment, and the description will be omitted as appropriate when the same effects are acquired in the case of the specific examples 2 and 3 and the case of the second embodiment. According to the data generation program and the system 9 of the first and second embodiments, by executing the data generation program, the data generation apparatus 1 can generate three-dimensional modeling data for modeling the modeled object 121 including the three-dimensional product 40, the cutting margin 56, the support columns 81 to 88, and the beams 111 and 112 by using the three-dimensional printer 11. The support columns 81 to 88 extend in the extending direction according to the arrangement condition, and one ends thereof in the extending direction are connected to the cutting margin 56 added to the three-dimensional product 40. The support columns 81 to

88 are removed together with the cutting margin 56 by removing the cutting margin 56 from the three-dimensional product 40 by the cutting apparatus 12. Thus, it is not necessary for the user to provide a step of removing the support columns 81 to 88 from the modeled object 121 in order to acquire the three-dimensional product 40 from the modeled object 121, separately from the step of removing the cutting margin 56 from the modeled object 121. In other words, the data generation program can generate three-dimensional modeling data for modeling the three-dimensional product 61 and the support columns 81 to 88 connected to the three-dimensional product 61 using the 3D printer 11, taking into consideration that the support columns 81 to 88 are removed from the three-dimensional product 40. The data generation program can automatically set the arrangement of the support columns 81 to 88 such that one ends thereof in the extending direction are connected to the cutting margin 56, which reduces the burden on the user compared with a conventional program. The CPU 2 of the present embodiment sets an extension range of the beam 111 based on extension ranges of the support columns 81 to 84 connecting to the beam 111, and sets an extension range of the beam 112 based on extension ranges of the support columns 85 to 88 connecting to the beam 112. Thus, the size of the beams 111 and 112 in the Z direction is constant over the Y direction, and also the size of the beams 111 and 112 in the Z direction can be minimized. Thus, according to the data generation program, the modeling time of the modeled object 121 can be shortened and the use amount of the material of the modeled object 121 can be reduced, compared with a case where the size of the beam 111 in the Z direction is set without considering the extension ranges of the support columns 81 to 84 connected to the beam 111 and the size of the beam 112 in the Z direction is set without considering the extension ranges of the support columns 85 to 89 connected to the beam 112.

[0040] The data generation program includes an instruction for executing processes (S22, S24) of generating three-dimensional cutting data for cutting and removing the cutting margin 56 and the one ends of the support columns 81 to 88 of the modeled object 121 by the cutting apparatus 12. In S25, the CPU 2 outputs three-dimensional modeling data and three-dimensional cutting data (S25). Thus, the data generation program and system 9 can save the user's time and effort to generate three-dimensional cutting data separately from three-dimensional modeling data. Since the data generation program and the system 9 can generate three-dimensional cutting data using the process necessary to generate three-dimensional modeling data, the process of generating the three-dimensional cutting data can be simplified compared with a case where the three-dimensional cutting data is generated separately from the three-dimensional modeling data.

[0041] The data generation program includes an instruction for executing a process of accepting designation of a cutting surface at one side in the height direction of the three-dimensional product 40 (S4, S6). In S31 and S32, the extending direction, the width direction, and the height direction of the support columns 81 to 88 are set based on the designated cutting surface. The data generation program can improve convenience of the user, as compared with a program in which the user cannot designate a cutting surface. The data generation program can save the time and labor of the user to set the extending direction, the width direction, and the height direction of the support columns 81 to 88 separately from the cutting surface.

[0042] The arrangement conditions acquired in S30 include the width Q in the width direction of the support columns 81 to 88, the height H in the height direction of the support columns 81 to 88, and the pitch P that is the distance corresponding to the interval between adjacent support columns. Therefore, the data generation program can improve the degree of freedom in the arrangement of the support columns 81 to 88 as compared with a program in which the user cannot specify the arrangement condition. The CPU 2 of the present embodiment uses the center D of the three-dimensional product 61 in the Y direction to set the arrangement of the support columns 81 to 88, which can reduce the possibility that the support columns 81 and 88 are arranged at deviated positions in the Y direction.

[0043] The data generation program includes an instruction for setting an extension range in the width direction of the support column based on the arrangement condition acquired in S30 (S32) and identifying the outer peripheral edge 66 of the cutting surface in an extension range in the width direction of the support columns 81 to 88 based on the three-dimensional data of the three-dimensional product 61 (S37, S52). The support columns 81 to 88 or the support column 131 to 138 extending by the height H in the height direction thereof are set at positions corresponding to the outer peripheral edge 66 of the identified cutting surface in the cutting margin 56 added to the three-dimensional product 40 (S42, S43, S55, S56). The data generation program can generate three-dimensional molding data in which the lengths of the support columns 81 to 88 in the extending direction are set shorter than a case where the support columns 81 to 88 are set at positions corresponding to the center of the cutting surface. This enables the data generation program to shorten the modeling time of the modeled object 121 and to reduce the amount of use of the material of the modeled object 121.

[0044] The position corresponding to the outer peripheral edge 66 of the data generation program is a position at which at least part of one ends of the support columns 81 to 88 in the extending direction is in contact with the outer peripheral edge 66. Thus, the data generation program can generate three-dimensional modeling data in which the lengths of the support columns 81 to 88 in the extending direction are set to be shorter than a case where the one ends of the support columns 81 to 88 in the extending direction is separated from the outer peripheral edge 66. This enables the data generation program to shorten the modeling time of the modeled object 121 and to reduce the amount of use of the material of the modeled object 121.

[0045] S37 or S52 identifies the outer peripheral edge 66 of the cutting surface of the three-dimensional product 61 to which the cutting margin 56 is added, based on the maximum or minimum value in the extending direction of the three-dimensional data of the three-dimensional product 61 within the extension range of the support columns 81 to 88 in the width direction. This enables the data generation program to identify the outer peripheral edge 66 of the cutting surface in the cutting margin 56 by a simple process as compared with a case where the entire three-dimensional data of the three-dimensional product 61 is scanned to identify the outer peripheral edge 66 of the three-dimensional product 61.

[0046] The data generation program and the three-dimensional modeling system of the present invention are not limited to the above-described embodiments, and various changes may be made without departing from the spirit of the present invention. For example, the following modifications may be added as appropriate.

(A) The configuration of the data generation apparatus 1 and the system 9 may be changed as appropriate. The data generation apparatus 1 may be a dedicated apparatus or may be a general-purpose apparatus, as long as the data generation apparatus 1 can generate three-dimensional modeling data based on three-dimensional data representing a three-dimensional product. The system 9 may include only the 3D printer 11 and the cutting apparatus 12, and the data generation process may be executed by a controller of at least one of the 3D printer 11 and the cutting apparatus 12.

(B) The program including instructions for executing the data generation process of FIG. 2 may be stored in a storage device of the system 9 by the time when the CPU 2 executes the program. Accordingly, each of the acquisition method and the acquisition route of the program, and a device storing the program may be changed as appropriate. The program to be executed by the CPU 2 may be received from another apparatus via a cable or wireless communication and may be stored in a storage device such as a flash memory. The other apparatuses include, for example, a PC and a server connected via a network.

(C) Each step of the process executed by the system 9 is not limited to an example performed by the data generation apparatus 1, and some or all of the processes executed by the system 9 may be executed by other electronic devices (for example, ASIC) of the system 9. Each step of the data generation process may be executed in a distributed manner by a plurality of electronic devices (for example, a plurality of CPUs). The order of steps of the data generation process may be changed as necessary. In the data generation process, a step may be omitted and a step may be added as necessary. It is also within the scope of the present disclosure that an operating system (OS) and so on operating on the data generation apparatus 1 performs a part or all of the data generation process based on an instruction from the CPU 2. For example, the following changes may be added to the data generation process as appropriate.

[0047] At least one of the processes from S22 to S24 may be omitted or may be executed by the cutting apparatus 12 instead of the data generation apparatus 1. For example, the data generation apparatus 1 may execute the process of S22 and may output the three-dimensional modeling data and the three-dimensional cutting data generated in S25 to the cutting apparatus 12. The cutting apparatus 12 may execute the processes of S23, S24 based on the three-dimensional modeling data and the three-dimensional cutting data outputted from the data generation apparatus 1.

[0048] At least one of the processing for setting the support columns 81 to 88, 91 to 98, 101 to 108, 131 to 138, 141 to 148, the beams 111 to 116, and the four columns 71 to 74 may be changed as appropriate. The processing of S12 may be omitted such that the four columns 71 to 74 are not set. In this case, both ends of the beams 111 and 112 in the width direction of the support columns 81 to 88 set in the specific example 1 of the first embodiment may be formed in a particular shape without being connected to the columns 71 to 74. The extension range of the beam 111 in the height direction of the support columns 81 to 84 may be set independently of the extension range of the support columns 81 to 84 connected to the beam 111, and may be set according to the extension range of the three-dimensional product 61 similarly to the columns 71 to 74, for example. At least one of the processes from S3 to S9 may be omitted, and the setting method may be changed as appropriate. The arrangement condition acquired in S30 may not include at least one of the width in the width direction of the support columns 81 to 88, the height in the height direction of the support columns 81 to 88, and the interval between adjacent support columns 81 to 88, or may include other conditions. The method of identifying the outer peripheral edge 66 may be appropriately changed. The three-dimensional data may be scanned to identify an outer peripheral surface of the three-dimensional product 61 and to identify the outer peripheral edge 66. The outer peripheral edge 413 may be identified based on three-dimensional data of the three-dimensional product 40, and the outer peripheral edge 66 may be identified based on the identified outer peripheral edge 413 and the cutting margin 56. The support columns 81 to 88 set for the three-dimensional product 61 may be arranged at positions that are shifted by particular distances from the outer peripheral edge 66 based on the outer peripheral edge 66 of the three-dimensional product 61. In the support columns 81 to 88 set for the three-dimensional product 61, at least part of one end of the support columns 81 to 88 at the three-dimensional product 61 side in the extending direction may be connected to the cutting margin 56, and the arrangement may be determined without identifying the outer peripheral edge 66 of three-dimensional product 61.

DESCRIPTION OF REFERENCE SIGNS

[0049]

1: Data generation apparatus
2: CPU
3: ROM
4: RAM
5: Memory
7: Display
8: Operation part
9: Three-dimensional modeling system
10: Bus
11: 3D printer
12: Cutting apparatus

Claims

1. A data generation program comprising instructions for causing a controller of a computer to perform:

    a data acquisition step of acquiring three-dimensional data representing a three-dimensional shape of a three-dimensional product;
    a condition acquisition step of acquiring an arrangement condition for arranging a support column to the three-dimensional product, the support column being connected to the three-dimensional product;
    a direction setting step of setting an extending direction, a width direction, and a height direction of the support column;
    a cutting-margin addition step of adding a cutting margin of a particular thickness to a cutting surface of the three-dimensional product at one side in the height direction;
    a support-column setting step of setting the support column in accordance with the arrangement condition, the support column extending in the extending direction, one end of the support column in the extending direction being connected to the cutting margin added to the three-dimensional product;
    a beam setting step of setting a beam, the beam being spaced from the three-dimensional product having the cutting margin in the extending direction, the beam extending in the width direction, the beam being connected to an other end of the support column in the extending direction;
    a modeling-data generation step of generating three-dimensional modeling data for modeling a modeled object by using a three-dimensional modeling apparatus, the modeled object including the three-dimensional product, the cutting margin, the support column, and the beam; and
    an output step of outputting the three-dimensional modeling data.

2. The data generation program according to claim 1, further comprising instructions for causing the controller to perform a cutting-data generation step of generating three-dimensional cutting data for cutting and removing, with a cutting apparatus, the cutting margin and the one end of the support column in the modeled object,
wherein the output step includes outputting the three-dimensional modeling data and the three-dimensional cutting data.

3. The data generation program according to claim 1 or 2, further comprising instructions for causing the controller to perform a reception step of receiving designation of the cutting surface at the one side in the height direction,
wherein the direction setting step includes setting the extending direction, the width direction, and the height direction of the support column based on the designation of the cutting surface.

4. The data generation program according to any one of claims 1 to 3, wherein the arrangement condition includes a width of the support column in the width direction, a height of the support column in the height direction, and a length based on an interval between adjacent support columns.

5. The data generation program according to claim 4, further comprising instructions for causing the controller to perform:

a range setting step of setting an extension range of the support column in the width direction based on the arrangement condition; and

an edge identifying step of identifying, based on the three-dimensional data, an outer peripheral edge of the cutting surface within the extension range of the support column in the width direction,

wherein the support-column setting step includes setting the support column to the cutting margin at a position corresponding to the outer peripheral edge of the cutting surface identified by the edge identifying step, the support column extending by the height in the height direction, the cutting margin being added to the three-dimensional product and connected to the one end in the extending direction.

6. The data generation program according to claim 5, wherein the position corresponding to the outer peripheral edge is a position at which at least part of the one end of the support column in the extending direction is in contact with the outer peripheral edge.

7. The data generation program according to claim 5 or 6, wherein the edge identifying step includes identifying the outer peripheral edge of the cutting surface of the three-dimensional product to which the cutting margin is added, based on a maximum value or a minimum value of the three-dimensional data in the extending direction within the extension range in the width direction of the support column.

8. A three-dimensional modeling system comprising:

a data acquisition part that acquires three-dimensional data representing a three-dimensional shape of a three-dimensional product;

a condition acquisition part that acquires an arrangement condition for arranging a support column to the three-dimensional product, the support column being connected to the three-dimensional product;

a direction setting part that sets an extending direction, a width direction, and a height direction of the support column;

a cutting-margin addition part that adds a cutting margin of a particular thickness to a cutting surface of the three-dimensional product at one side in the height direction;

a support-column setting part that sets the support column in accordance with the arrangement condition, the support column extending in the extending direction, one end of the support column in the extending direction being connected to the cutting margin added to the three-dimensional product;

a beam setting part that sets a beam, the beam being spaced from the three-dimensional product having the cutting margin in the extending direction, the beam extending in the width direction, the beam being connected to an other end of the support column in the extending direction;

a modeling-data generation part that generates three-dimensional modeling data for modeling a modeled object by using the three-dimensional modeling apparatus, the modeled object including the three-dimensional product, the cutting margin, the support column, and the beam;

a cutting-data generation part that generates three-dimensional cutting data for cutting and removing, with a cutting apparatus, the cutting margin and the one end of the support column in the modeled object;

an output part that outputs the three-dimensional modeling data and the three-dimensional cutting data;

a three-dimensional modeling apparatus that models the modeled object in accordance with the three-dimensional modeling data; and

a cutting apparatus that cuts the modeled object in accordance with the three-dimensional cutting data to obtain the three-dimensional product.

FIG. 1

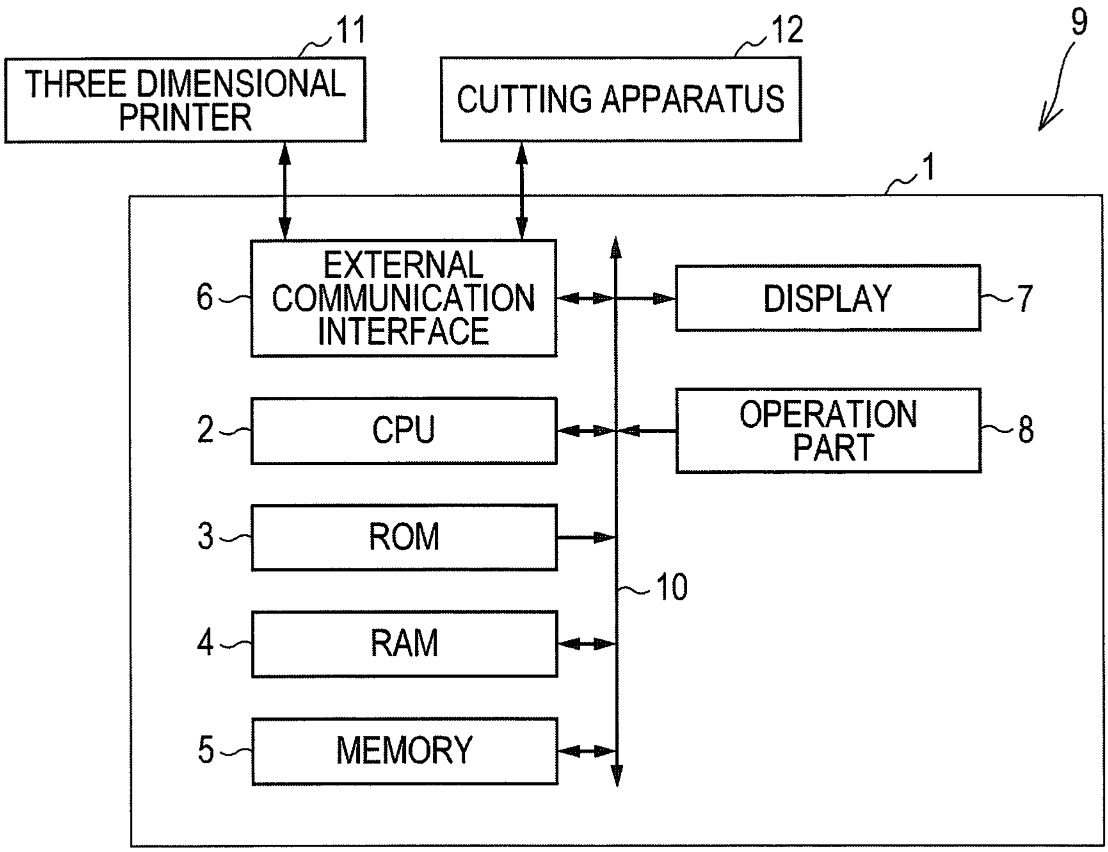

THREE DIMENSIONAL PRINTER
11
CUTTING APPARATUS
12
9
1
EXTERNAL COMMUNICATION INTERFACE
6
DISPLAY
7
CPU
2
OPERATION PART
8
ROM
3
10
RAM
4
MEMORY
5

FIG. 2

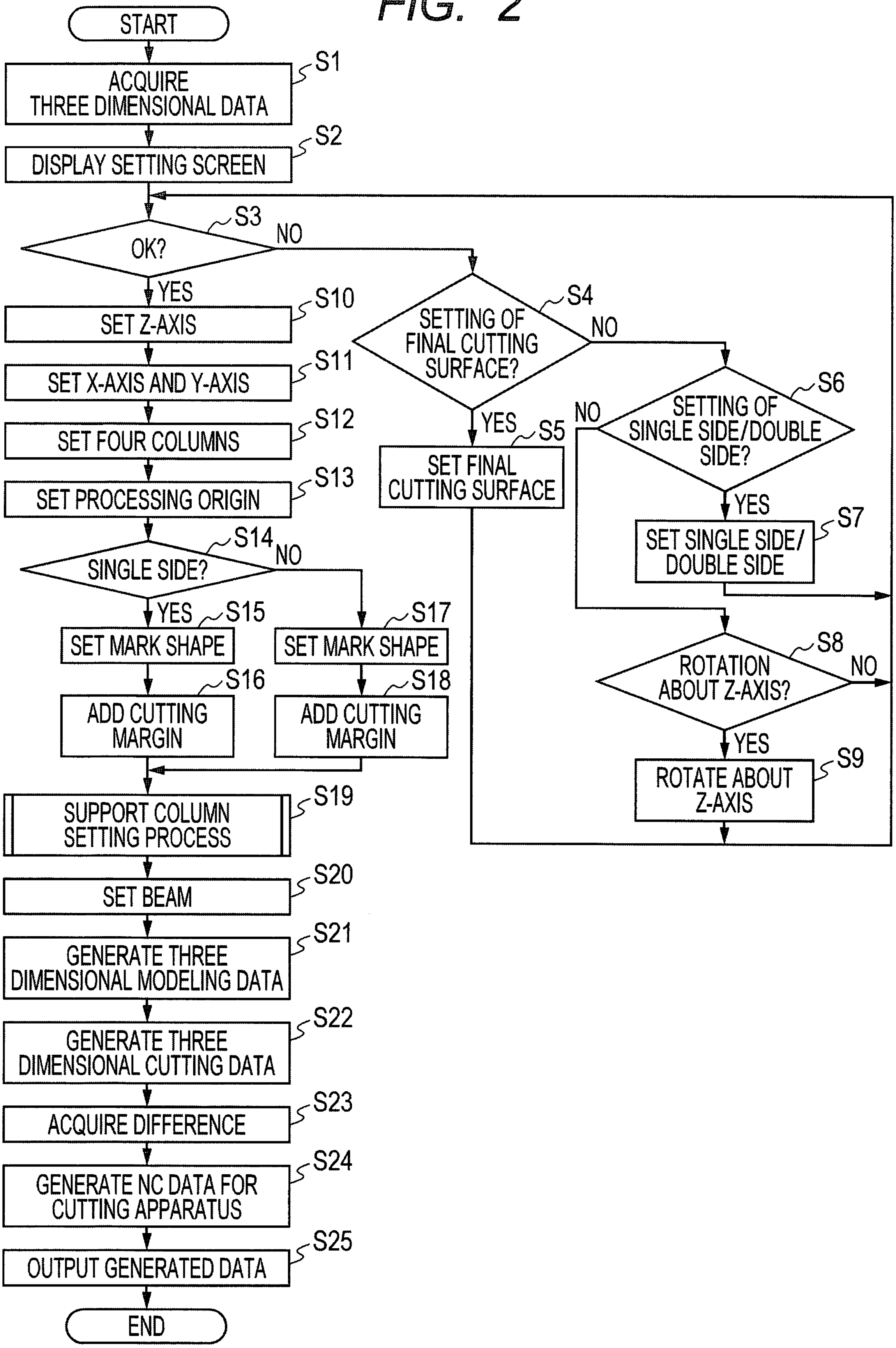
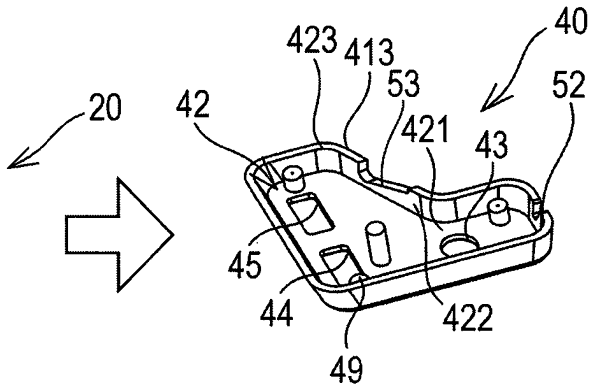

START
ACQUIRE THREE DIMENSIONAL DATA
S1
DISPLAY SETTING SCREEN
S2
OK?
S3
NO
YES
SETTING OF FINAL CUTTING SURFACE?
S4
NO
YES
S5
SET FINAL CUTTING SURFACE
SETTING OF SINGLE SIDE/DOUBLE SIDE?
S6
NO
YES
SET SINGLE SIDE/ DOUBLE SIDE
S7
ROTATION ABOUT Z-AXIS?
S8
NO
YES
ROTATE ABOUT Z-AXIS
S9
SET Z-AXIS
S10
SET X-AXIS AND Y-AXIS
S11
SET FOUR COLUMNS
S12
SET PROCESSING ORIGIN
S13
SINGLE SIDE?
S14
NO
YES
S15
SET MARK SHAPE
S16
ADD CUTTING MARGIN
S17
SET MARK SHAPE
S18
ADD CUTTING MARGIN
SUPPORT COLUMN SETTING PROCESS
S19
SET BEAM
S20
GENERATE THREE DIMENSIONAL MODELING DATA
S21
GENERATE THREE DIMENSIONAL CUTTING DATA
S22
ACQUIRE DIFFERENCE
S23
GENERATE NC DATA FOR CUTTING APPARATUS
S24
OUTPUT GENERATED DATA
S25
END

FIG. 3

ID	THREE DIMENSIONAL COORDINATE
1	(X1, Y1, Z1)
2	(X2, Y2, Z2)
...	...



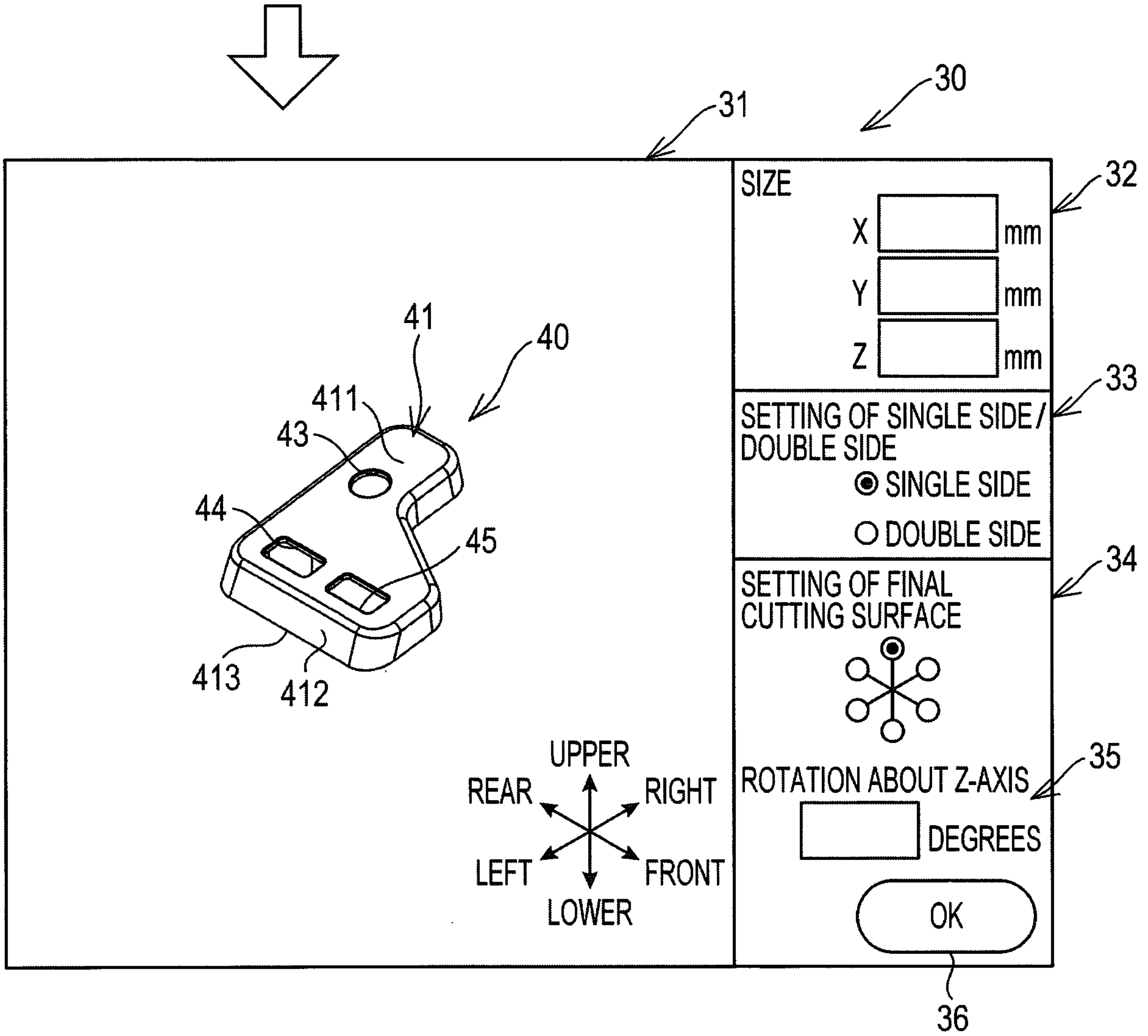


FIG. 4A

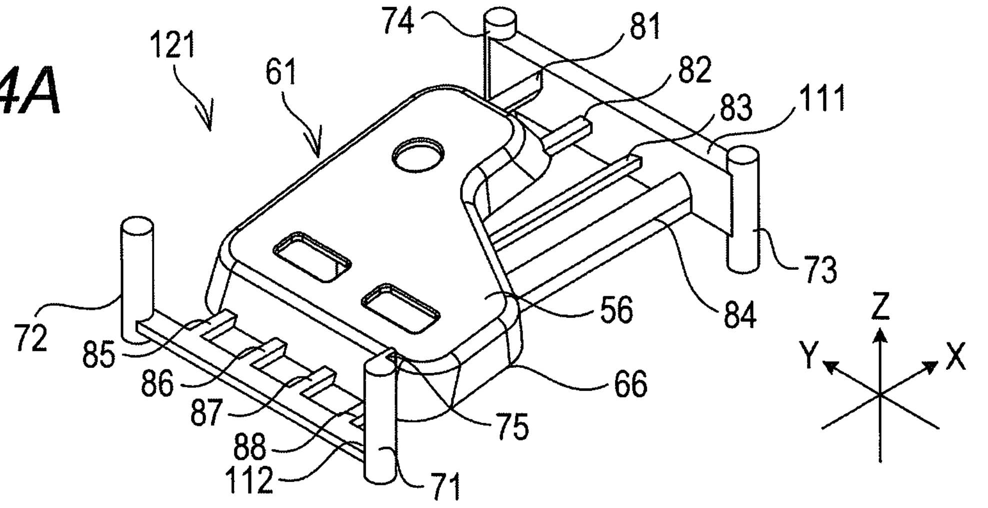


FIG. 4B

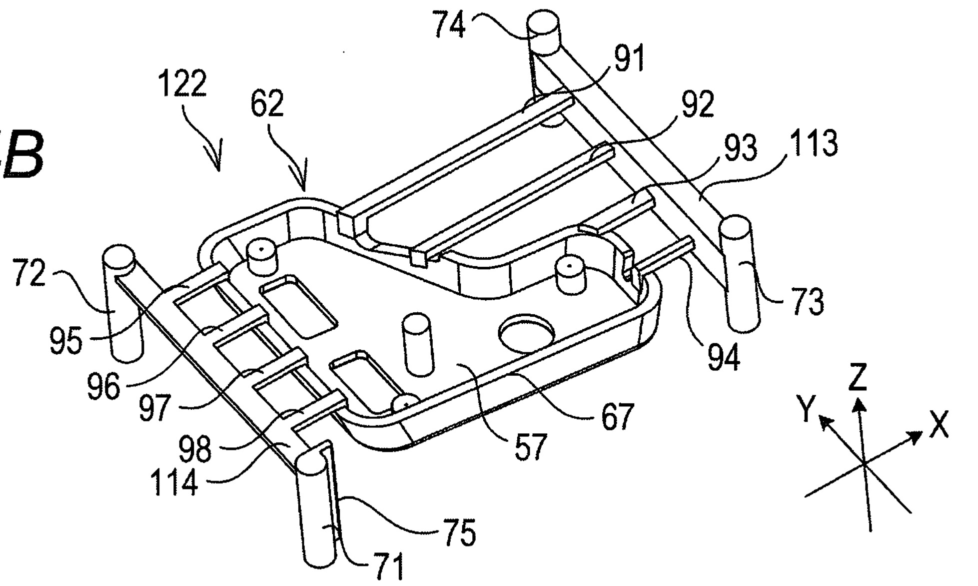


FIG. 4C

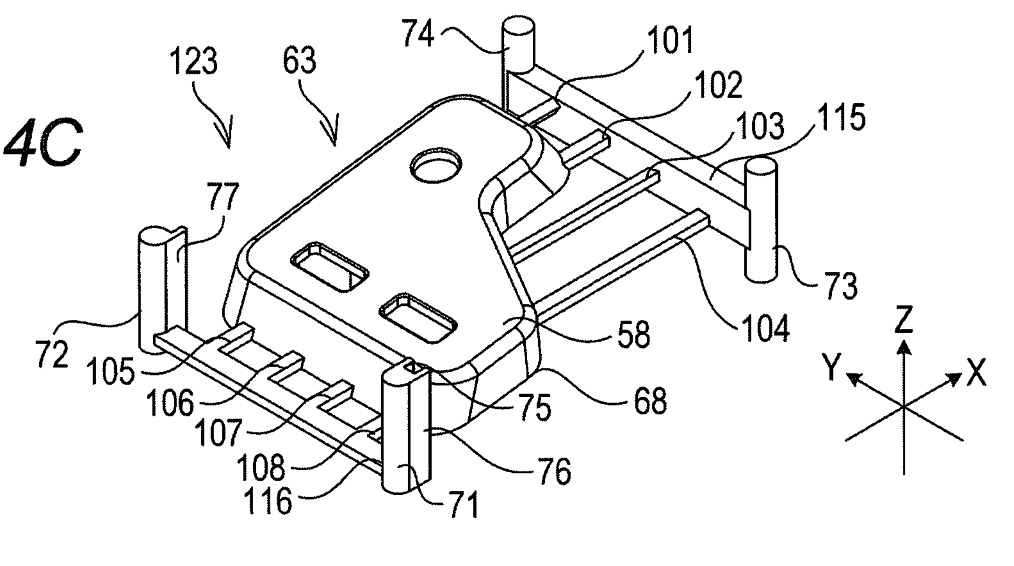


FIG. 5

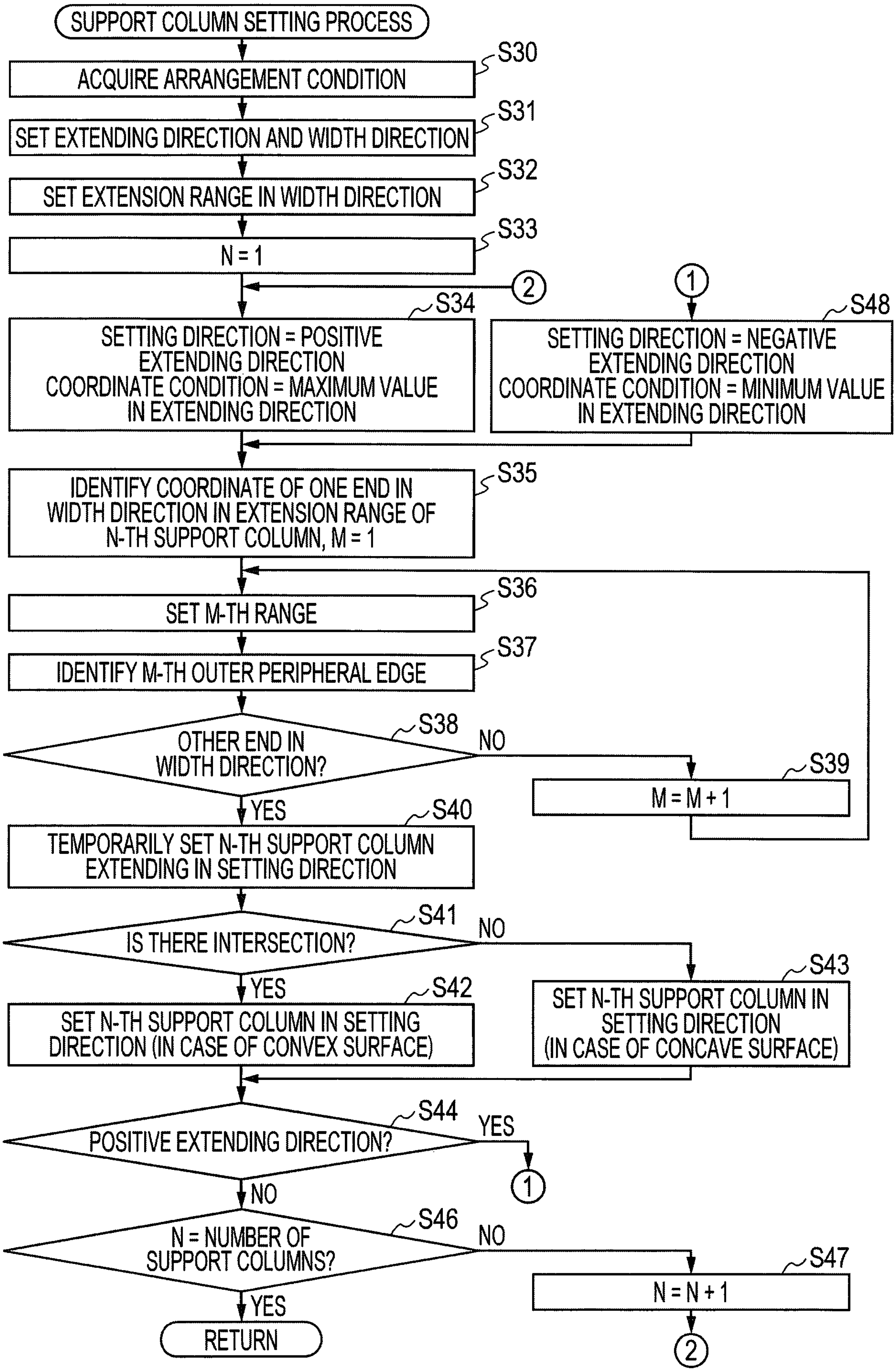

SUPPORT COLUMN SETTING PROCESS
S30
ACQUIRE ARRANGEMENT CONDITION
S31
SET EXTENDING DIRECTION AND WIDTH DIRECTION
S32
SET EXTENSION RANGE IN WIDTH DIRECTION
S33
N = 1
2
S34
SETTING DIRECTION = POSITIVE EXTENDING DIRECTION COORDINATE CONDITION = MAXIMUM VALUE IN EXTENDING DIRECTION
1
S48
SETTING DIRECTION = NEGATIVE EXTENDING DIRECTION COORDINATE CONDITION = MINIMUM VALUE IN EXTENDING DIRECTION
S35
IDENTIFY COORDINATE OF ONE END IN WIDTH DIRECTION IN EXTENSION RANGE OF N-TH SUPPORT COLUMN, M = 1
S36
SET M-TH RANGE
S37
IDENTIFY M-TH OUTER PERIPHERAL EDGE
S38
OTHER END IN WIDTH DIRECTION?
NO
S39
M = M + 1
YES
S40
TEMPORARILY SET N-TH SUPPORT COLUMN EXTENDING IN SETTING DIRECTION
S41
IS THERE INTERSECTION?
NO
S43
SET N-TH SUPPORT COLUMN IN SETTING DIRECTION (IN CASE OF CONCAVE SURFACE)
YES
S42
SET N-TH SUPPORT COLUMN IN SETTING DIRECTION (IN CASE OF CONVEX SURFACE)
S44
POSITIVE EXTENDING DIRECTION?
YES
1
NO
S46
N = NUMBER OF SUPPORT COLUMNS?
NO
S47
N = N + 1
2
YES
RETURN

FIG. 6

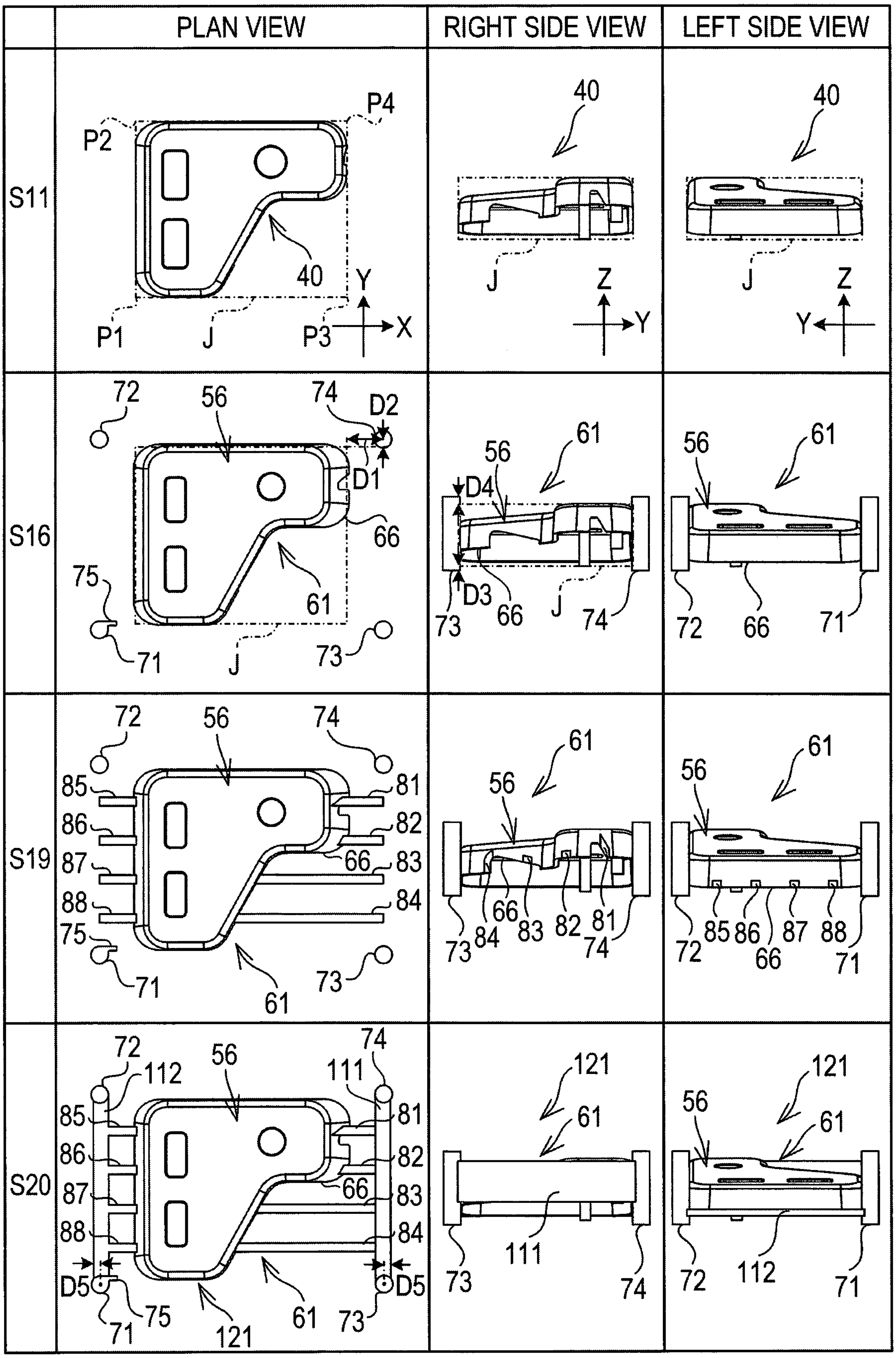

PLAN VIEW
RIGHT SIDE VIEW
LEFT SIDE VIEW
S11
S16
S19
S20
P1
P2
P3
P4
J
40
X
Y
Z
56
61
66
71
72
73
74
75
D1
D2
D3
D4
D5
81
82
83
84
85
86
87
88
111
112
121

FIG. 7

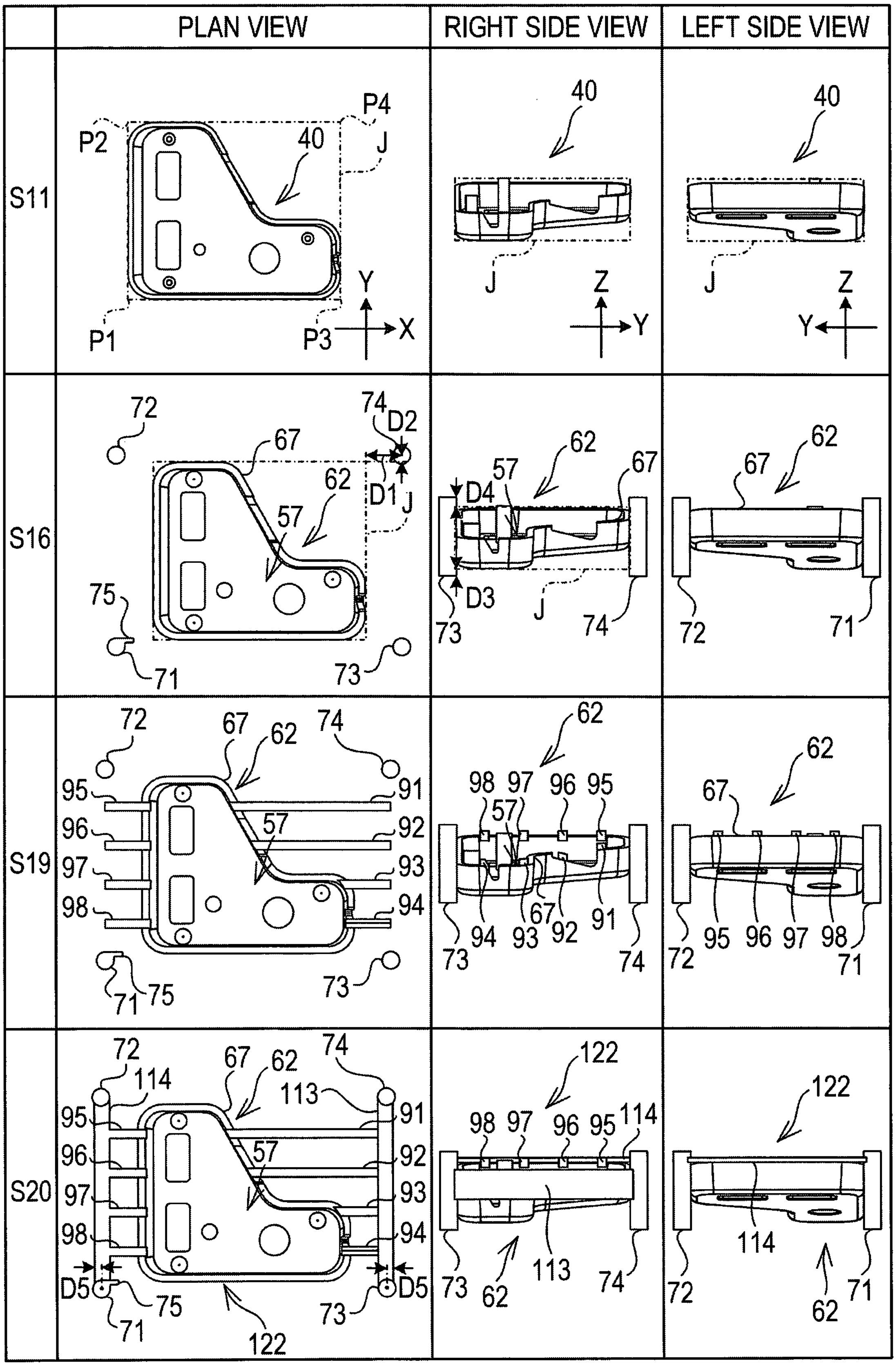

PLAN VIEW
RIGHT SIDE VIEW
LEFT SIDE VIEW
S11
S16
S19
S20
P1
P2
P3
P4
J
40
X
Y
Z
D1
D2
D3
D4
D5
57
62
67
71
72
73
74
75
91
92
93
94
95
96
97
98
113
114
122

FIG. 8

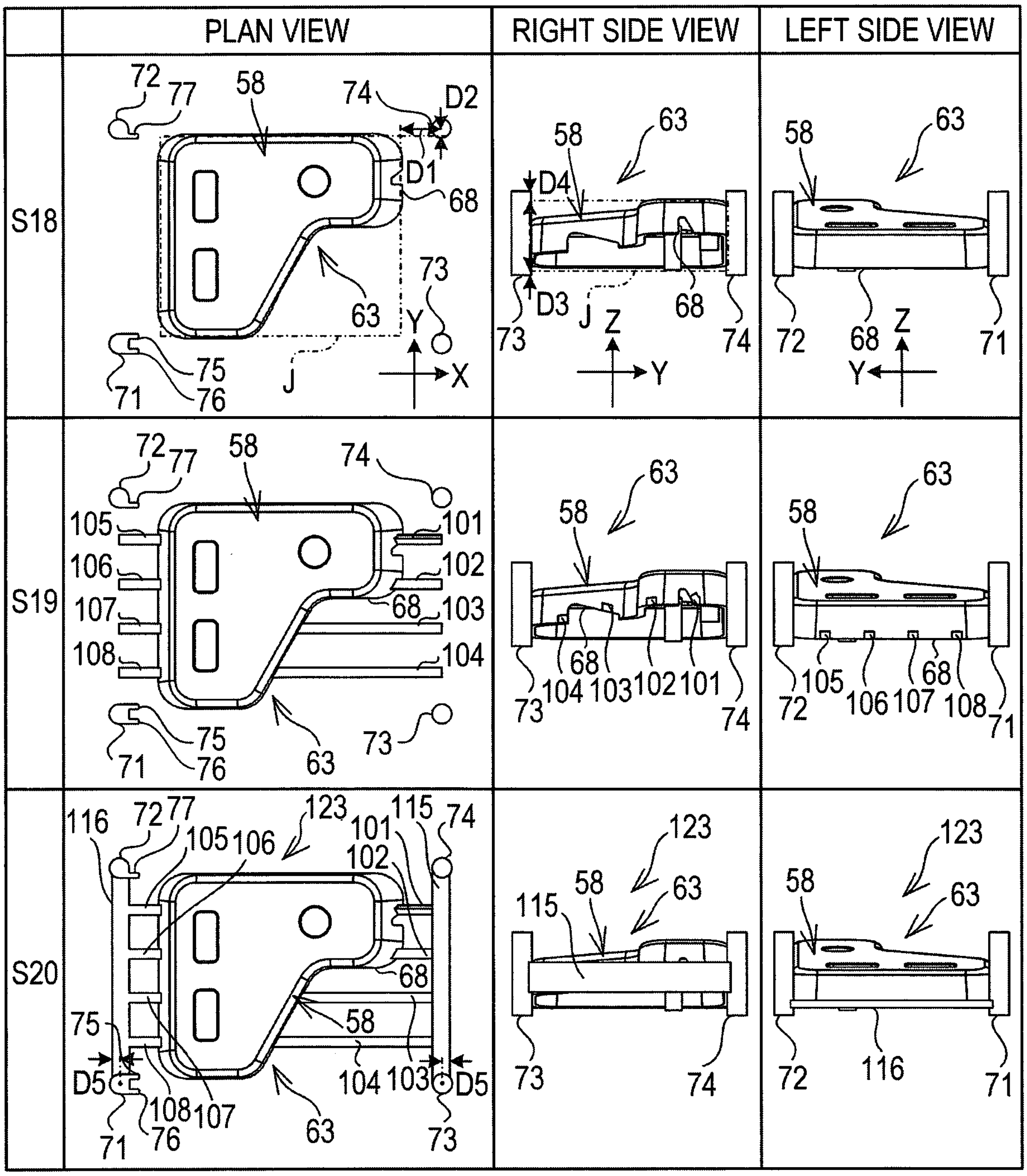

PLAN VIEW
RIGHT SIDE VIEW
LEFT SIDE VIEW
S18
S19
S20
72 77 58 74 D2 D1 68 73 63 75 76 71 J Y X
58 63 D4 D3 73 J Z Y 68 74
58 63 72 68 Z Y 71
72 77 58 74 105 106 107 108 101 102 68 103 104 75 76 71 63 73
63 58 68 73 104 103 102 101 74
63 58 105 72 106 107 68 108 71
116 72 77 105 106 123 101 115 74 102 68 58 75 D5 108 107 76 71 63 104 103 D5 73
123 115 58 63 73 74
123 58 63 72 116 71

FIG. 9

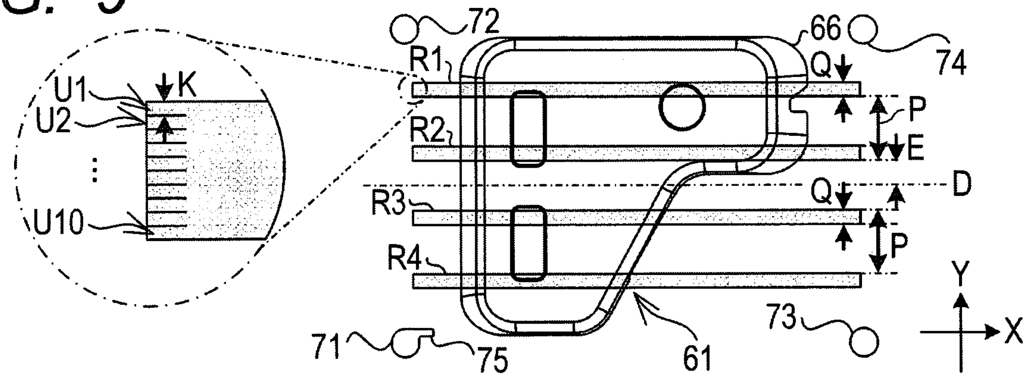

U1 K U2 U10
72 66 74 R1 Q P R2 E D R3 Q P R4 Y X 71 75 61 73

FIG. 10

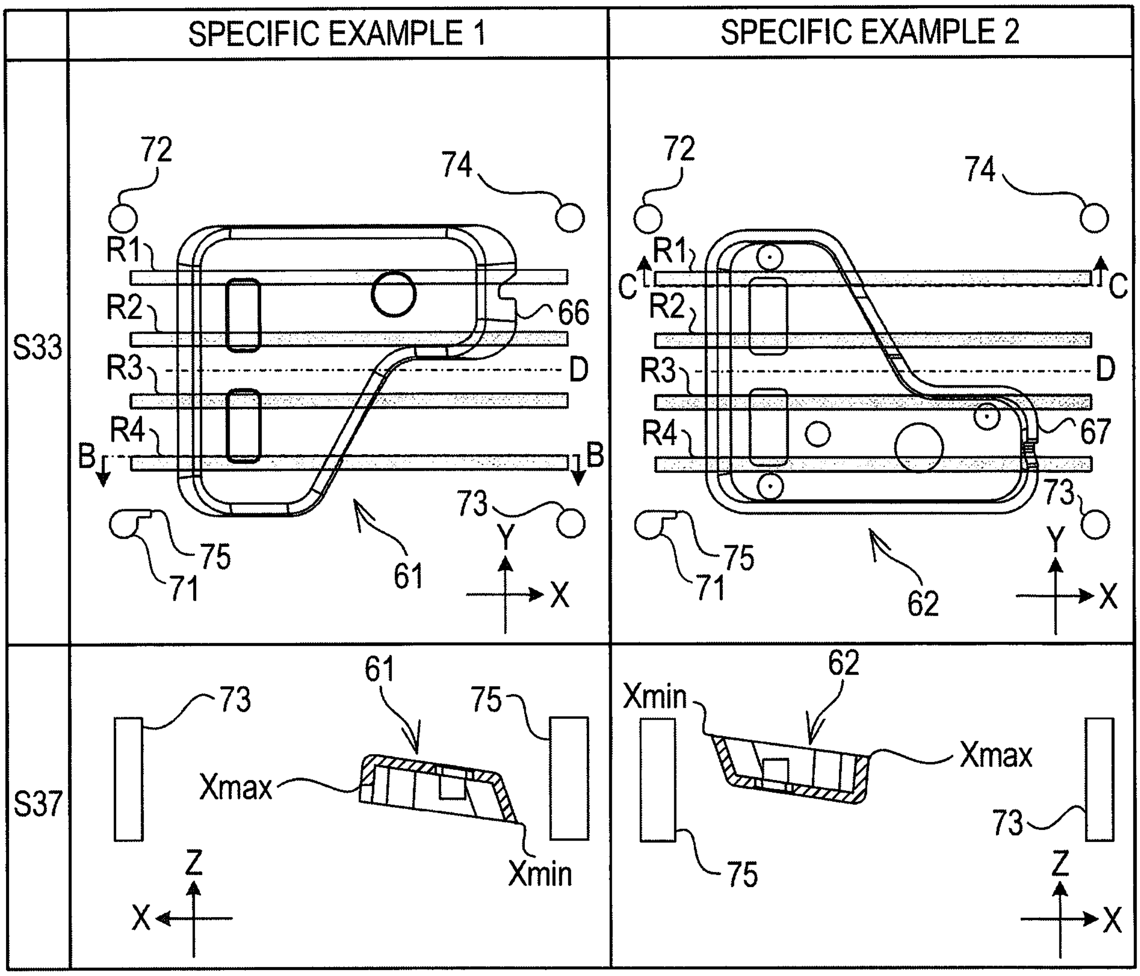

SPECIFIC EXAMPLE 1
SPECIFIC EXAMPLE 2
S33
S37
72
74
R1
R2
R3
R4
B
D
66
61
71
73
75
C
67
62
Y
X
Z
Xmax
Xmin

FIG. 11

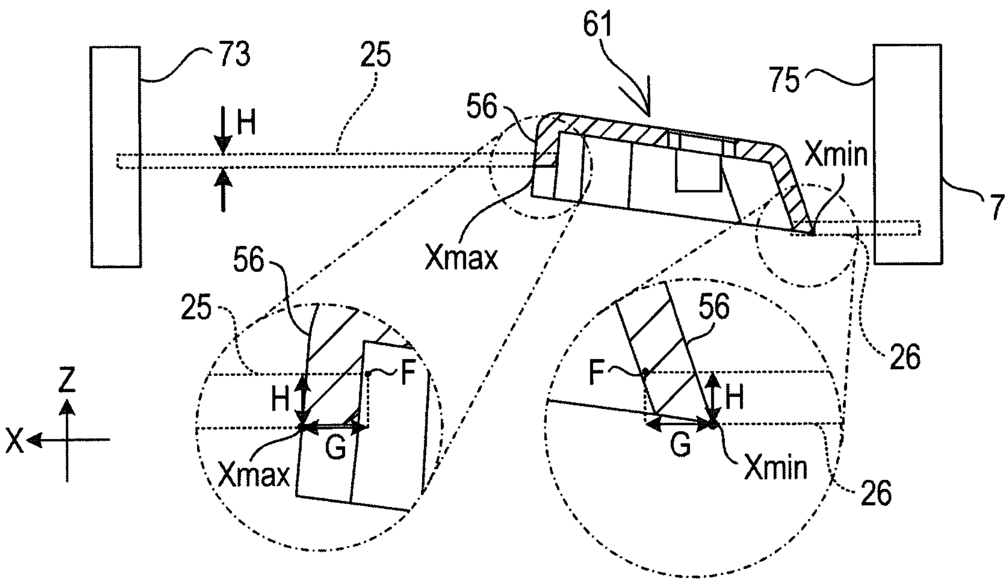

73
25
61
56
75
71
H
Xmin
Xmax
26
F
G
Z
X

FIG. 12

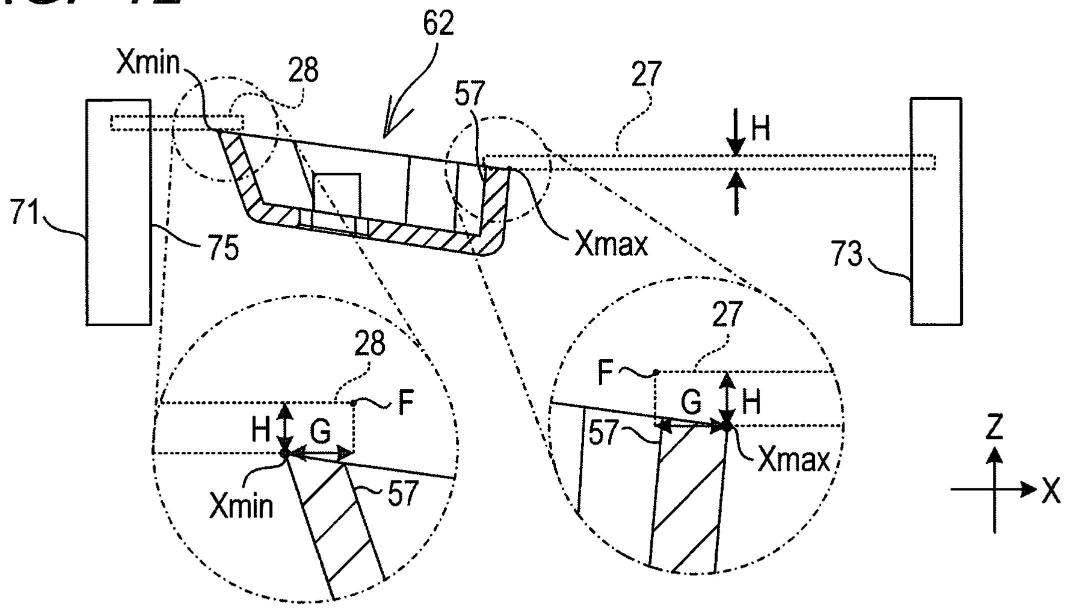


FIG. 13

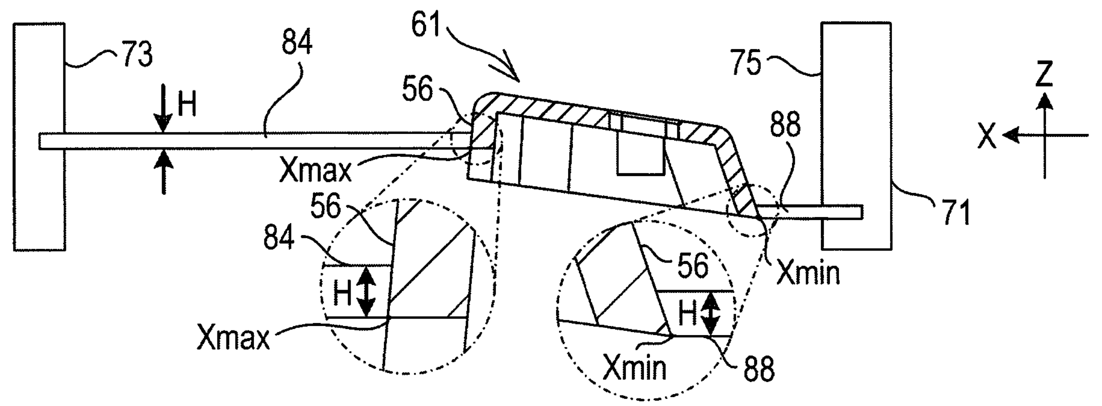


FIG. 14

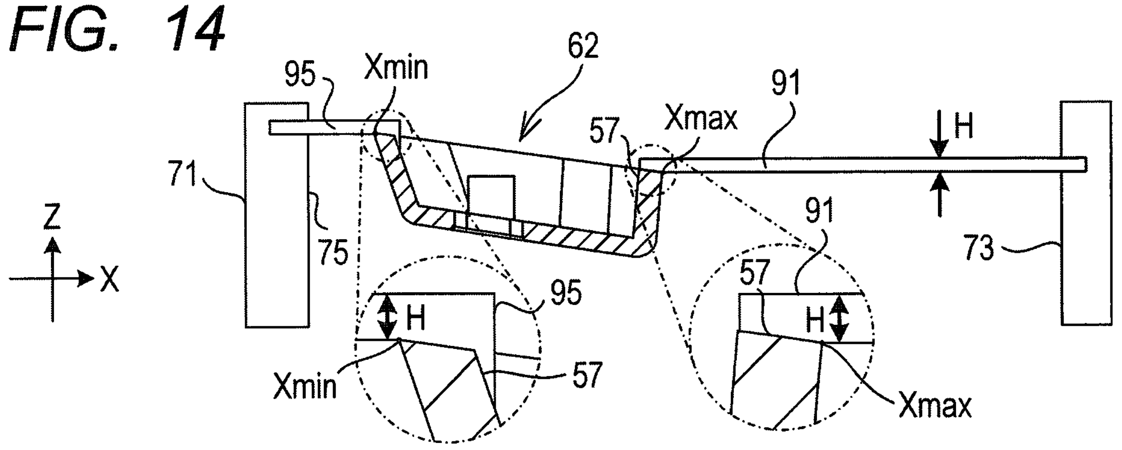


FIG. 15

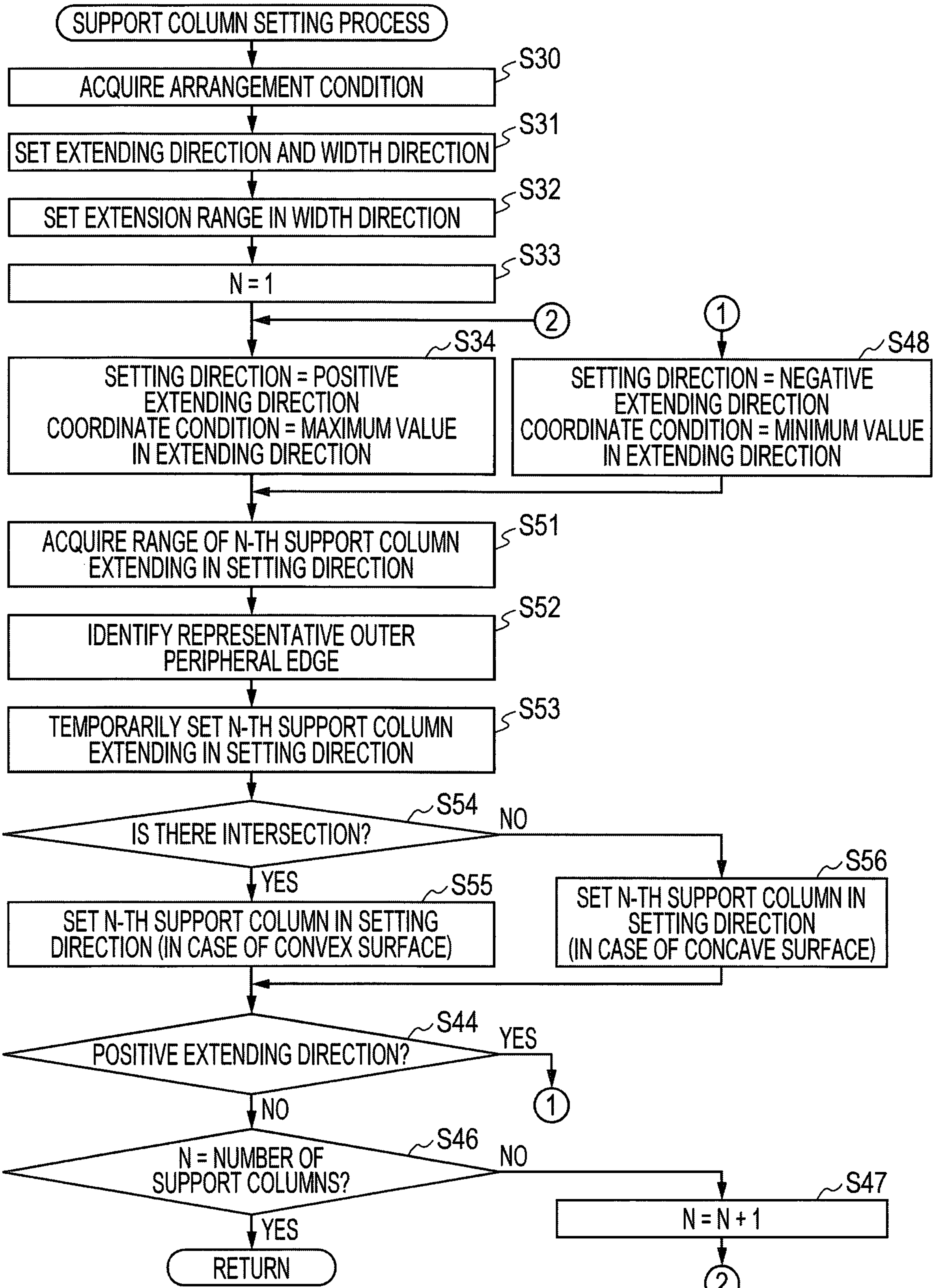

SUPPORT COLUMN SETTING PROCESS
S30
ACQUIRE ARRANGEMENT CONDITION
S31
SET EXTENDING DIRECTION AND WIDTH DIRECTION
S32
SET EXTENSION RANGE IN WIDTH DIRECTION
S33
N = 1
2
1
S34
SETTING DIRECTION = POSITIVE EXTENDING DIRECTION COORDINATE CONDITION = MAXIMUM VALUE IN EXTENDING DIRECTION
S48
SETTING DIRECTION = NEGATIVE EXTENDING DIRECTION COORDINATE CONDITION = MINIMUM VALUE IN EXTENDING DIRECTION
S51
ACQUIRE RANGE OF N-TH SUPPORT COLUMN EXTENDING IN SETTING DIRECTION
S52
IDENTIFY REPRESENTATIVE OUTER PERIPHERAL EDGE
S53
TEMPORARILY SET N-TH SUPPORT COLUMN EXTENDING IN SETTING DIRECTION
S54
IS THERE INTERSECTION?
NO
YES
S55
SET N-TH SUPPORT COLUMN IN SETTING DIRECTION (IN CASE OF CONVEX SURFACE)
S56
SET N-TH SUPPORT COLUMN IN SETTING DIRECTION (IN CASE OF CONCAVE SURFACE)
S44
POSITIVE EXTENDING DIRECTION?
YES
1
NO
S46
N = NUMBER OF SUPPORT COLUMNS?
NO
S47
N = N + 1
2
YES
RETURN

FIG. 16A

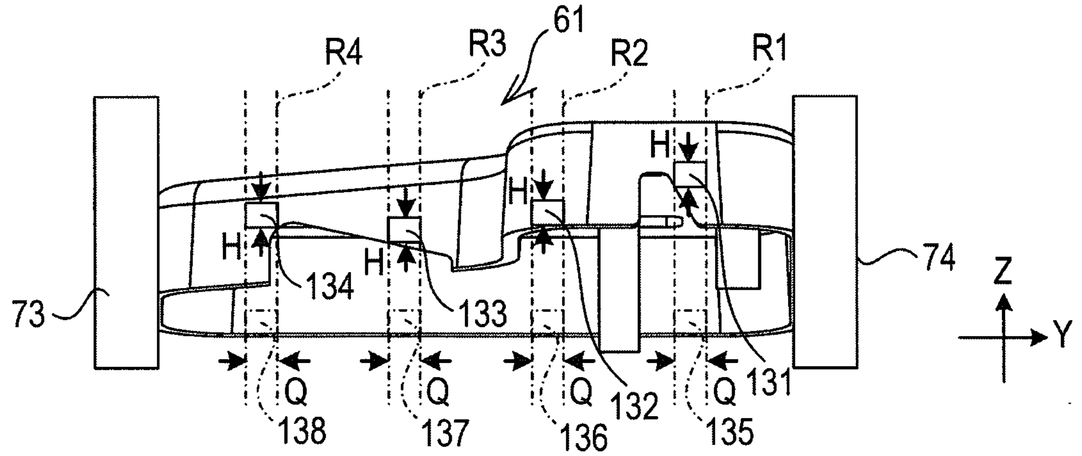
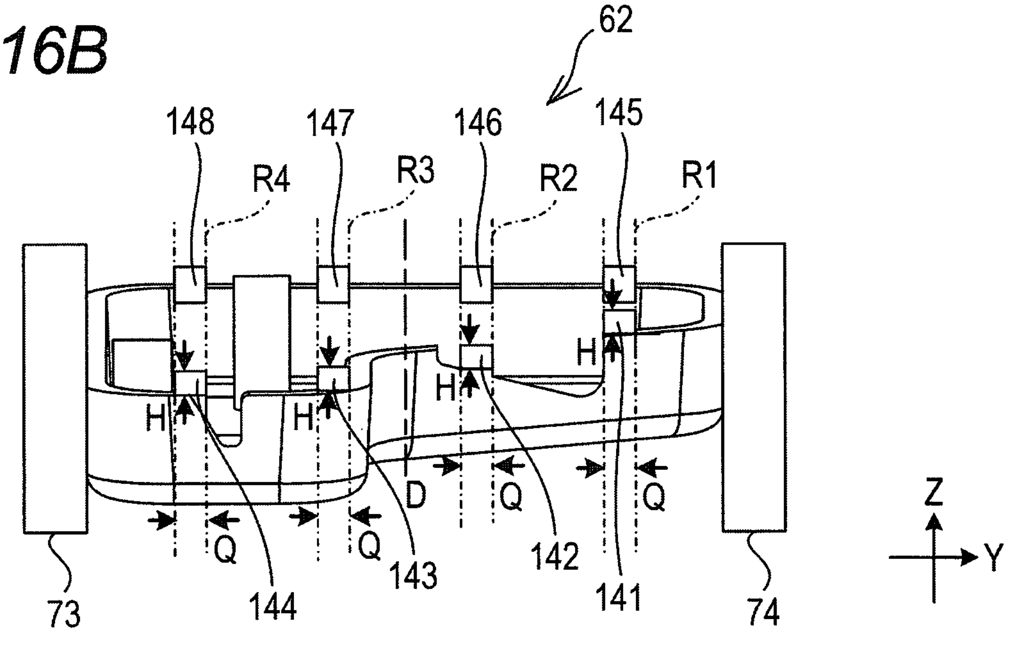


FIG. 16B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/010046

A. CLASSIFICATION OF SUBJECT MATTER
B33Y 10/00(2015.01)i; B33Y 30/00(2015.01)i; B33Y 50/00(2015.01)i; B29C 64/386(2017.01)i; B29C 64/40(2017.01)i; B33Y 40/20(2020.01)i; B22F 10/47(2021.01)i; B22F 10/60(2021.01)i; B22F 10/80(2021.01)i
FI: B29C64/386; B29C64/40; B33Y50/00; B33Y10/00; B33Y30/00; B33Y40/20; B22F10/47; B22F10/60; B22F10/80
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
B33Y10/00; B33Y30/00; B33Y50/00; B29C64/386; B29C64/40; B33Y40/20; B22F10/47; B22F10/60; B22F10/80

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-136605 A (TOSHIBA CORP.) 14 May 2003 (2003-05-14) paragraphs [0008]-[0009], [0026]-[0032], [0043], fig. 1-15	1-8
A	JP 2017-077683 A (ROLAND D G KK) 27 April 2017 (2017-04-27) paragraphs [0007]-[0060], fig. 1-8	1-8
A	JP 2013-184405 A (CASIO COMPUTER CO., LTD.) 19 September 2013 (2013-09-19) paragraphs [0012]-[0127], fig. 1-20	1-8
A	JP 2017-518199 A (DWS S.R.L) 06 July 2017 (2017-07-06) paragraphs [0039]-[0137], fig. 1-7	1-8

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 May 2021 (12.05.2021)	25 May 2021 (25.05.2021)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/010046

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2003-136605 A	14 May 2003	(Family: none)	
JP 2017-077683 A	27 Apr. 2017	(Family: none)	
JP 2013-184405 A	19 Sep. 2013	US 2013/0244040 A1 paragraphs [0042]-[0147], fig. 1-20 CN 103302858 A	
JP 2017-518199 A	06 Jul. 2017	US 2018/0215098 A1 paragraphs [0044]-[0142], fig. 1-7 CN 106164913 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003136605 A **[0003]**